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BITUMINOUS SANDS OF NORTHERN ALBERTA

OCCURRENCE
AND
ECONOMIC POSSIBILITIES

REPORT ON INVESTIGATIONS TO THE END OF 1924

S. C. ELLS

MINES BRANCH
DEPARTMENT OF MINES
OTTAWA
1926
No. 632

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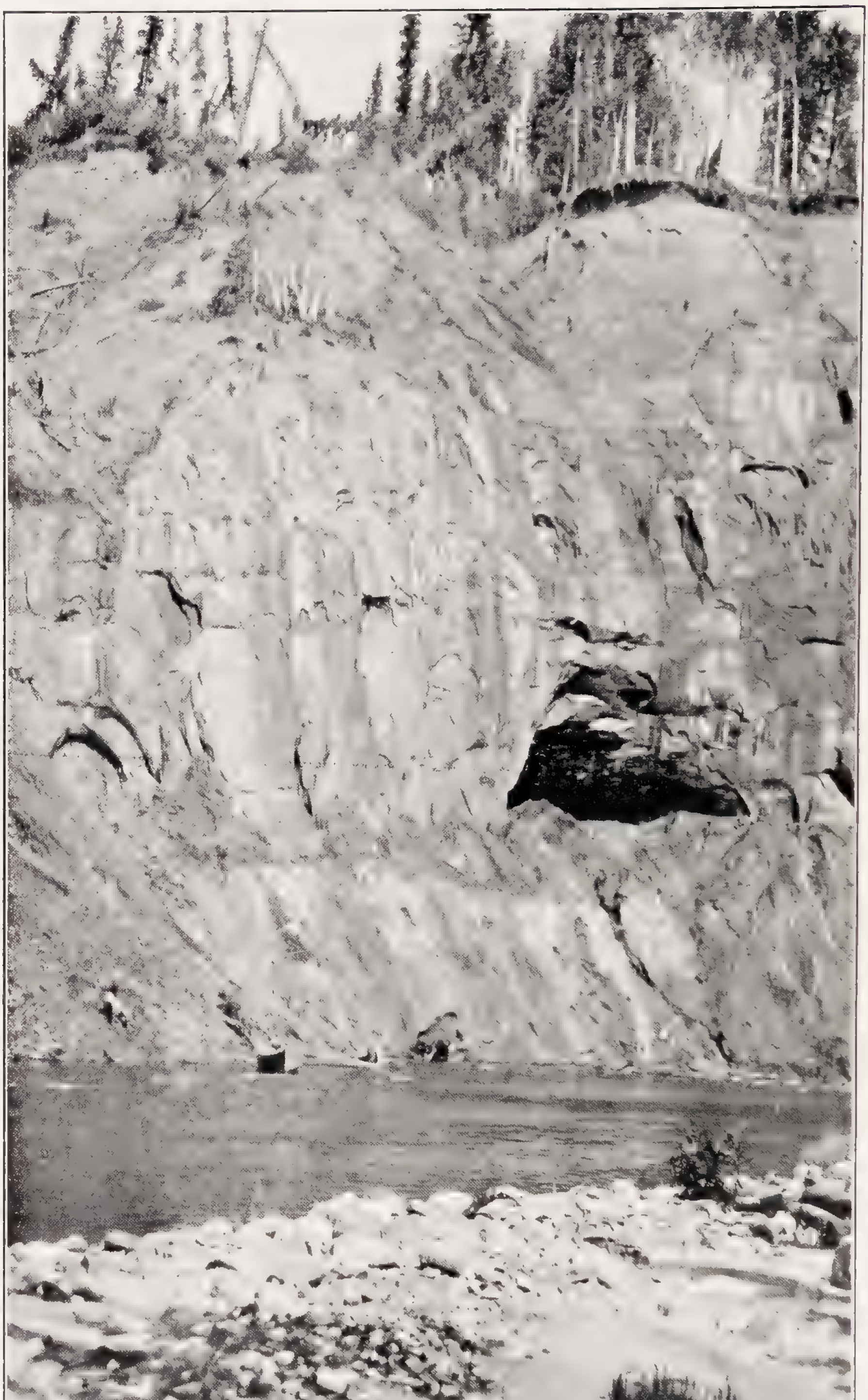

Exposure of bituminous sand on north side of Steepbank river, illustrating massive structure and cleavage typical of the richer grades of bituminous sand.

CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

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BY

S. C. Ells

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PREFACE

The "Preliminary Report on the Bituminous Sands of Northern Alberta," No. 281, was issued by the Department of Mines in 1914. The edition was exhausted some years ago.

The report was based on observations made in 1913 during a period of eight weeks' field work. Analyses and physical tests of representative samples of the bituminous sands were later made by the writer, and were included as an appendix.

Subsequent and more detailed field work has adduced additional information bearing on the Alberta deposits. It has not, however, necessitated any material change in views expressed or conclusions arrived at in the original report. Supplementing the present report, a series of detailed topographical maps and sections have been prepared for publication.

The writer has had occasion to visit nearly all of the more important asphaltic deposits throughout the United States, British West Indies, France, Italy, and Switzerland. Remarks relating to these foreign deposits are based largely on personal observation.

Should present conditions not favour the immediate commercial development of the deposit of bituminous sand in northern Alberta, it appears unwise to artificially stimulate such development. It is improbable that the potential value of these deposits, as a national asset, will decrease.

The writer desires to thank those who, by advice, or otherwise, have assisted in securing data embodied in this report. His thanks are especially due to the many men who, as field assistants, or in other capacities, and frequently under conditions involving discomfort and hardship, have cordially co-operated in carrying out a somewhat extensive programme of field work.

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*In accompanying map carton.

BITUMINOUS SANDS[1] OF NORTHERN ALBERTA

INTRODUCTORY

Exploration in northern Alberta commenced with the advent of fur traders, in 1778. Subsequently, other explorers, either in private, or official capacities, have reported on certain physical features and natural resources.[2]

Present knowledge of the geology of northern Alberta is based largely on the work of Dr. Selwyn, Dr. Dawson, Dr. Robert Bell, R. G. McConnell, and F. H. McLearn. Mr. McConnell's report, published in 1893, still constitutes the most complete description available of the general geological features of much of the country lying between the Peace and Athabaska rivers.

Although much is known regarding the general areal geology of northern Alberta, there is very little definite information available regarding the extent and actual value of the mineral resources within the area. Notwithstanding the lack of detailed exploration and prospecting—which until recent years have been handicapped through absence of adequate transportation facilities—the occurrence of deposits of bituminous sands and sandstones has long been recognized. The recent completion of the Alberta and Great Waterways railway should encourage more detailed exploration, and facilitate the development of such mineral and other natural resources as may be found within the area adjacent to the new line.

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1 For reference to use of the term "bituminous sand" see Appendix I.

2 Harman, D.W.—A Journal of Voyages and Travels in the Interior of North America, 1820.
Tache, A. A.—Sketch of North West America, 1820.
Ogilvie, Wm.—Report on Athabaska and Peace rivers, Alberta, 1884.
Reports of Select Committees of the Senate, enquiring into the resources of the Mackenzie Basin, 1888-1891.
Fawcett, T.—Exploratory survey of Athabaska and Churchill rivers, 1889.
McConnell, R. G.—Report on a Portion of the District of Athabaska; Part D, Annual Report, Geol. Surv., Can., 1891.
Report of Senate Committee, 1907. "Canada's Fertile Northland."
Preble, E. A.—North American Fauna, No. 27; Athabaska-Mackenzie Region, 1908.
Crean, F. J.—Report of Exploration, 1908-09, issued by Department of Interior.
Ponton, A. W.—Survey of Fifth Meridian, from township 77 to township 107, 1909.
Selwyn, A. R. C.—Report on Exploration in British Columbia, Geol. Surv. Can., 1875.
Dawson, Geo. M.—Report on the Northern Part of British Columbia and the Peace River Country, Geol. Surv. Can., 1879.
Bell, Robert—Report on part of the Basin of the Athabaska River, Geol. Surv. Can., 1884.
Geol. Surv. Can., Sum. Rept. 1894, Vol. VII, No. 553, p. 6A.
Malcolm, Wyatt—Oil and Gas Prospects of the Northwest Provinces of Canada, Geol. Surv., Can., 1913.
Ells, S. C.—Sum. Rept. Mines Branch, 1913.
Bituminous Sands of Northern Alberta, Mines Branch Report No. 281, 1914.
Sum. Rept. Mines Branch, 1914.
" " 1915.
" " 1916.
" " 1920.
" " 1922.
" " 1923.
" " 1924.
Bituminous Sands of Northern Alberta, Mines Branch Report No. 625, 1924.
Mines Branch Maps Nos. 536, 537, 538, 539, 540, and 541, (1915).
Mines Branch Maps Nos. 633, 634, 635, 636, 637, 638, 639, 640, (1925).
Mines Branch Sections Nos. 1, 2, 3, 4, (1925).
McLearn, F. H.—Athabaska River Section, Alberta, Sum. Rept. of Geol. Surv., Dept. of Mines, 1916.
New Species of Pelecypods from the Cretaceous of Northern Alberta. Museum Bulletin No. 29, Geol. Surv., 1919.

The present report has been prepared not only as a means of expressing certain conclusions that have been arrived at, but also as a possible basis for future investigation within the McMurray area.[1] It is not the writer's intention to attempt the introduction or reproduction of a mass of miscellaneous data on recognized methods and standards of road construction,[2] manufacturing processes, and laboratory procedure.[3] A complete discussion of such technical considerations will be found in an extensive literature, and in contributions to technical journals, and to the proceedings of various societies.

The three outstanding features presented by a consideration of the bituminous sands of northern Alberta are:—

(1) That the deposit represents the largest known body of solid asphaltic material.

(2) That the deposit is, as yet (April, 1925) commercially undeveloped.

(3) That practically all asphaltic materials used in Canada are imported from foreign countries.

There is a reasonable probability that conditions will eventually permit of a considerable commercial development of the Alberta deposit. Assuming this to be so, it is of importance to determine how this development can best be undertaken and an industry established on a sound economic basis.

Up to the present, practically all information regarding the Alberta deposit, as well as much of the work that has been done in investigating the economic value of the bituminous sand itself, may be attributed to the Department of Mines. Under existing conditions, it is but reasonable that a department of the Federal Government should undertake the initial work, since the greater part of the area is held under Government reserve.[4] Consequently, until quite recently, there has been little inducement for private individuals or companies to interest themselves in what has proved to be a somewhat extensive investigation.

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[1] For convenience the McMurray area may be arbitrarily defined as lying between W. long. 111° and 112°, and between N. lat. 56° 30′ and 57° 30′. All exposures of bituminous sand in this area lie within a radius of 80 miles of McMurray.

[2] Twenty years ago, it was possible to include in a bibliography of reasonable length, the outstanding books and articles dealing with asphaltic pavements. During the intervening period, authoritative literature on the subject has grown to such an extent that this is no longer possible. The writer considers that publications issued by the Asphalt Association, New York, are now sufficiently complete to answer nearly all practical requirements.

[3] Abraham, H., Asphalt and Allied Substances; D. Van Nostrand Co., New York, 1918.
Spielmann, P. E.; Bituminous Substances; Ernest Benn Ltd., London, 1925.
Prevost, Hubbard and Reeve, Chas. S., Methods for Examination of Bituminous Road Materials; Bull. 314, U.S. Dept. of Agriculture, 1915.
Hubbard, Prevost and Field, F. C.; A Practical Method for Determining the Relative Stability of Fine-Aggregate Asphalt Mixtures, twenty-eighth Annual Meeting of Am. Soc. for Testing Materials, June, 1925.
Hubbard, Prevost; Research Work to Improve Asphalt Paving Mixtures. The Asphalt Association, New York, 1925.

[4] In May, 1912, the privilege of filing bituminous sand claims was withdrawn by Order in Council. Although prior to that date many claims had been recorded, the titles to certain of these have since lapsed. At the present time (April, 1925), apart from 3 small areas reserved for the use of the Parks Branch, Department of the Interior, the aggregate area of claims in good standing does not exceed 20,000 acres.
Information regarding conditions under which leases are granted, may be obtained from the Superintendent of Mining Lands, Department of the Interior, Ottawa.

There are three lines along which commercial development of Alberta bituminous sands may be attempted. These are:—

1. Use of the bituminous sand in a more or less crude form as a wearing surface for streets and highways, and as a basis for the manufacture of asphalt mastic.

2. Various commercial applications of the bitumen when separated from the associated sand aggregate.

3. Destructive distillation of the crude bituminous sand or of partially purified bitumen with recovery of liquid hydrocarbons.

In the following pages each of these possibilities will be very briefly considered.

CHAPTER I

GENERAL DESCRIPTION OF AREA UNDERLAIN BY BITUMINOUS SAND

The surface of the area underlain by bituminous sand may be described as a peneplain, much of which is covered by swamp and muskeg. Through this plain the more important streams, excepting only the Clearwater and the Athabaska, have cut narrow, notch-like valleys. On emerging above the rim of these valleys one reaches the level country almost at once. With such a topography, outcrops of bituminous sand are thus confined to the slopes of older valleys, and to cutbanks along present water-courses.

The Athabaska and Clearwater valleys constitute the chief topographical features of this area. From a study of topographical maps which accompany this report, it is seen that the lower portion, at least, of Clearwater valley constitutes the true easterly continuation of Athabaska valley, and that the present Athabaska river, south of the latitude of McMurray, flows through a much younger,—and probably in part post-glacial valley. It is also evident from the size and character of the Clearwater-Athabaska valley, that the volume of water was at one time very much greater than at present although as yet no adequate drainage connexion or connexions toward the south or southeast have been definitely identified. Upham[1] suggests that:—

. . . . within the time after the ice-sheet retreated beyond the valley of the lower Saskatchewan, and before its melting upon Hudson bay and the adjoining country permitted lake Agassiz to gain an outlet to the northeast, it seems certain that the ice must have been melted upon a large region north of the Saskatchewan basin, where drainage now passes east by the Churchill and north by the Mackenzie, but was then pent up in lakes by the ice barrier and caused to flow to the south. Lake Agassiz thus received the waters of the upper Churchill, and of the basins of the Athabaska and Peace rivers, the great head streams of the Mackenzie; and the Churchill and probably also the upper Mackenzie basin, continued to be tributary to this lake through all its lower stages of outflow to Hudson bay.

. . . . The exploration of the ancient shore-line is very difficult in that generally forest-covered region, and it must be many years before the boundaries and outlets of former bodies of water in the basins of the Peace and Mackenzie can be mapped; but it may be predicted with reasonable confidence, that these basins, now drained to the Mackenzie and the Arctic ocean, will sometime be found to have contained glacial lakes overflowing southeastward to lake Agassiz. Probably the earliest outlet from the glacial lake of the Peace river was across the watersheds to Lesser Slave lake and to the North Saskatchewan at its eastward bend, about 50 miles below Edmonton; and that the latest overflow from the Athabaska glacial lake appears to have formed a channel across the Mackenzie and Churchill divide near the famous Methy portage.

With the above clue to the ancient drainage system, an interesting problem is presented in determining a possible continuation of the Clearwater valley toward the southeast.

[1] Upham, Warren, "The Glacial Lake Agassiz," U.S. Geol. Surv., Vol. XXV, p. 64.

In ascending Athabaska river south of McMurray, a swiftly-flowing current, interrupted by frequent rapids, is encountered. Valley walls become more abrupt, river bottom areas are of negligible extent, and there is a marked increase in depth of valley. To the north of McMurray, however, the river is free from rapids. Elevations of valley walls show a marked and uniform decrease, and where these recede from the present stream river bottom lands of considerable extent are seen. For many miles both to the north and to the south of McMurray, exposures of bituminous sand are common.

On the other hand, the relatively limited size of the present Clearwater river, as compared with Clearwater valley itself, implies rather extensive river bottom areas which protect the main valley walls from present river erosion. Consequently, with the single exception of one outcrop in tp. 89, range 9, major exposures of bituminous sand are not seen immediately adjacent to the river.

The principal streams tributary to Athabaska and Clearwater rivers, include Christina, Hangingstone, and Horse rivers, Poplar creek, Steepbank, Beaver, Muskeg, McKay, Ells (formerly Moose), and Tar rivers, Calumet creek, Pierre, Firebag, and Marguerite (Cree) rivers. Along the lower reaches of each of these streams, valley walls are abrupt, and the zones in which drainage is effective are, as a rule, limited in extent. Throughout these narrow zones, there is in most places a fair growth of poplar, jackpine, or spruce, although a considerable percentage of such growth has been destroyed by fire, and large areas at a distance from the principal valleys are now almost covered by dense second-growth poplar and jackpine. In the softer Cretaceous sediments along the eastern slopes of Birch mountains, certain of the above streams have eroded important valleys. Particularly toward the headwaters of Pierre river, in ranges 14 and 15, there are well-exposed sections and these afford an excellent opportunity for palæontological study.

On leaving the valleys elevations gradually increase. Toward the northeast and east of Athabaska valley, large areas of country are covered by sand and sandy soil. In passing westward clay soil becomes predominant. It may be noted that surface deposits of sand furnish no indication of the class of overburden that may be encountered even at shallow depth.

In Table I, an attempt has been made to classify[1], provisionally, the soil and forest growth. This classification is based on notes made on many hundreds of miles of traverse lines. In many instances it has been difficult to differentiate poplar, spruce, and jackpine areas, since such growth is frequently intermixed. Spruce is usually found on bottom lands, along the smaller valleys, and in certain swamps. Owing to the irregular nature of such areas, it has been difficult to estimate definitely the total acreage of spruce.

Although the total acreage of merchantable timber constitutes a considerable area, stands of poplar, spruce, and jackpine are, as a rule, scattered and, individually, of limited extent. A somewhat extensive

[1] Since the above classification was compiled in 1923, portions of the area referred to have been burned over by forest fires.

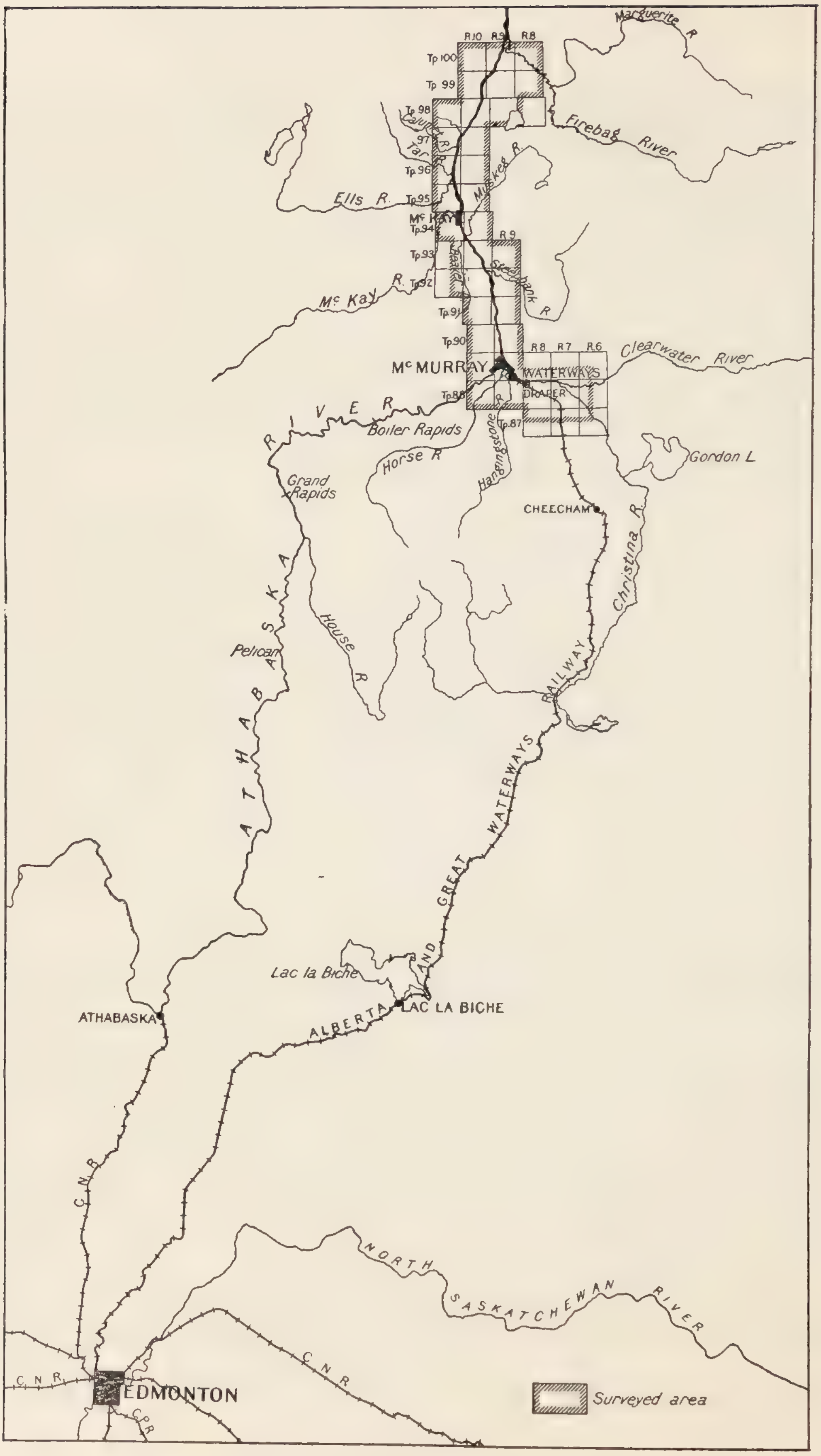


Fig. 1.—Index map showing position of McMurray area.

area of jackpine in tps. 96 and 97, ranges 10 and 11, east of Athabaska river, constitutes a notable exception. It is also unfortunate that many areas of clay soil are interrupted by the presence of numerous irregular muskegs and swamps.

TABLE I

Summary of Timber and Soil Conditions in McMurray Area

—		Character of forest growth					Character of soil			
		Muskeg, slough, and swamp	Poplar	Spruce	Jack-pine	Second growth brûlé	Clay soil	Sandy soil	River bottom lands	Water area
		per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Tp.	Range									
88	8	35·2	6·7	3·5	....	44·3	40·0	60·0	10·3	2·5
	9	30·2	11·5	11·7	....	37·6	89·9	10·1	....	0·8
	10	31·0	17·7	19·8	....	31·5	95·0	5·0	....	5·0
89 S. ⅔	8	40·7	15·9	12·1	6·9	24·4	19·5	80·5	1·0	0·2
	9	19·0	38·3	13·1	....	29·6	84·2	15·5	4·0	10·4
	10	38·5	21·2	11·4	....	28·9	67·5	32·5	0·3	2·5
90	9	37·4	26·0	13·5	....	23·1	25·8	74·2	10·4	7·2
	10	22·2	38·1	17·3	....	22·4	80·0	20·0	....	....
91	9	48·4	12·2	16·4	....	23·0	30·0	70·0	6·4	7·7
	10	38·9	10·6	21·6	....	28·9	60·0	40·0	....	....
92	9	48·7	13·7	7·9	9·8	19·9	20·0	80·0	2·0	5·4
	10	53·0	13·9	15·7	....	17·4	20·0	80·0	1·0	4·9
E½	11	49·9	16·9	13·0	....	20·2	40·0	60·0	....	....
93	9	54·6	5·6	4·3	....	35·5	19·3	80·7	....	....
	10	53·8	15·9	0·8	13·7	15·8	19·7	80·3	11·3	10·1
E½	11	28·0	12·1	0·7	24·7	34·5	....	100·0	....	1·0
94	9	57·0	9·3	12·8	....	20·9	20·0	80·0	....	2·7
	10	41·9	19·4	11·4	....	27·3	30·0	70·0	0·2	4·2
95	10	55·5	5·1	6·9	....	32·5	....	100·0	4·2	1·8
	11	52·6	11·7	10·1	0·3	35·3	16·0	84·0	1·8	7·6
96	10	34·9	6·9	3·2	2·9	32·2	0·9	99·1	....	0·1
	11	48·0	15·2	16·3	10·4	20·5	2·8	97·2	0·6	8·8
97	10	27·9	5·9	....	12·6	53·6	1·0	99·0	0·2	2·2
	11	42·6	16·7	3·9	16·4	20·4	1·0	99·0	0·6	6·1
98	9	3·4	....	....	2·2	94·4	....	100·0	....	11·1
	10	31·2	3·9	1·1	8·4	55·4	....	100·0	0·7	8·2
	11	47·6	1·4	....	2·4	48·6	2·8	97·2	....	....
99	8	....	....	....	0·8	99·2	....	100·0	0·1	0·3
	9	36·9	2·1	....	8·6	49·7	....	100·0	1·3	4·6
	10	44·0	6·1	....	9·5	40·4	....	100·0	2·3	6·3
100	8	15·3	1·5	0·8	0·8	82·6	0·4	99·6	....	1·5
	9	27·0	8·9	8·0	8·5	47·6	5·0	95·0	21·6	8·8
	10	61·2	6·5	....	15·5	16·8	1·5	98·5	....	....

In certain of the more promising outcrops the borders of the muskeg approach within a very short distance of the edge of the valley. The bearing of this feature on commercial development is referred to in the section dealing with prospecting and mining.

Throughout a considerable portion of the area, but more especially in river bottom lands, beaver dams have seriously interrupted natural drainage and caused the formation of numerous swamps and sloughs. A comparatively small financial expenditure would re-open many of the old channels and restore drainage.

As might be expected in a country covered by a heavy mantle of clay, and through which streams are deeply entrenched, slips in the bank constitute a notable feature. Individual slides bring down, at times, many thousands of tons of clay and soil. (Plate II.)

Slides of this type are prevalent, and their effect is most marked where the restraining influence of forest growth has been removed by fire. This is particularly noticeable along Christina river. Along the lower part of this stream the forest growth has, to a considerable extent, prevented serious slips in the banks. A few miles from the mouth, however, where the country has been burned over, the greater frequency of slides is at once seen. Removal of forest growth, as a preliminary to development work, would thus necessarily increase the probability of such slides; moreover, subsequent stripping operations, if undertaken on a large scale, would tend still further to affect the stability of adjacent ground. This feature is further emphasized by the presence of numerous fissures in the clay and other surface deposits. These fissures, in many places of considerable magnitude, lie roughly parallel with the top of the bank; and, in some cases, the strip of country thus affected and rendered unstable, extends quite 1,000 feet from the shore line. The fissured zone decreases in width as the overburden decreases in thickness.

OTHER MINERALS AND MINERAL WATERS

Iron Ore

It is of interest to note that fragments of iron ore have been found at a number of points throughout the McMurray area—notably on Steepbank and on Ells rivers. At one point on Steepbank river, approximately 5 miles from the mouth, two small excavations, 40 feet apart, were made in the northeast bank in 1914. In each instance a thin capping of bituminous sand overlies a compacted bed, 1 to 2 feet thick, consisting of fragments of siderite up to 20 pounds in weight. These fragments are not waterworn nor pitted, as would be the case with float that had been transported considerable distances. A bed of clay[1], 1 to 4 feet thick, underlies the iron ore, and rests upon well-bedded Devonian limestones.

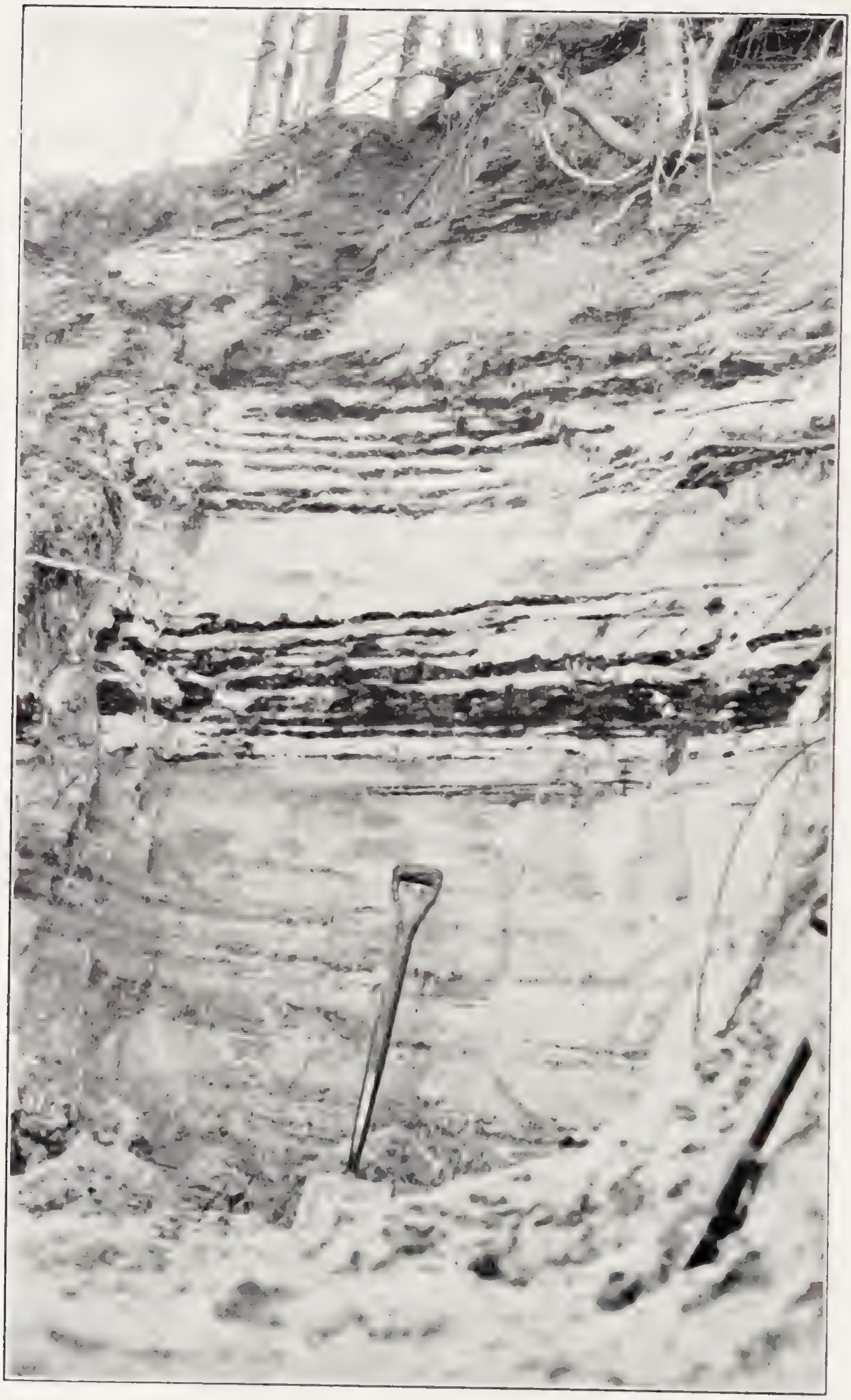
An analysis[2] of a representative sample of the iron ore showed: iron, 35 per cent; insoluble 18 per cent. So far as the writer's observation has gone, the occurrences referred to above, have no economic value. It may be added that clay ironstone, in the form of impure siderite, has a wide distribution, in association with rocks of Cretaceous age, in the western provinces of Canada. In some instances, the deposits appear to be due to the silting out of the fragments of ore, from the softer rocks of the formation. In no instance, however, have beds of economic importance been discovered.

---

[1] Residual clays are found throughout the McMurray area, and are probably derived from certain beds of highly argillaceous limestones. Reference to these clays will be found in "Notes on Clay Deposits of McMurray Area," by S. C. Ells, Mines Branch Bull. No. 10, 1915.

[2] Analysis by Chemical Laboratories, Mines Branch.

Typical bank on Christina river, illustrating effects of clay slides. The tendency for such slides to occur is intensified where forest growth has been removed by fire.



Typical section of marginal deposit on McClelland lake (L.S. 2, sec. 6, tp. 98, range 8), showing thin partings of bituminous sand, interbedded with unimpregnated sand.

Mineral Waters

Springs of mineral water have a wide distribution throughout the McMurray area, and samples were secured at a number of representative points in 1914. These samples were submitted to the Chemical Laboratories of the Mines Branch for analysis, with the following results:—

Results of Analyses

—	No. 1		No. 2		No. 3		No. 4	
	Parts per million	Grm. per Imp. gallon	Parts per million	Grm. per Imp. gallon	Parts per million	Grm. per Imp. gallon	Parts per million	Grm. per Imp. gallon
Calcium (Ca)	1,638	109·5	1,347	832·0	1,821	121·1	3,354	204·1
Magnesium (Mg)	385	25·7	585	36·1	571	38·0	1,021	62·1
Potassium (K)	296	19·7	336	20·7	496	33·0	192	11·6
Sodium (Na)	22,988	1,537·6	76,268	4,720·0	21,184	1,409·0	84,076	5,117·7
Bicarbonic acid (HCO_3)	469	31·3	372	22·9	530	35·0	36	2·1
Carbonic acid (CO_3)	nil	nil	nil	nil	nil	nil	nil	nil
Chlorine (Cl)	36,188	2,419·5	118,636	7,329·3	39,792	2,647·0	127,960	7,788·9
Sulphuric acid (SO_4)	4,144	277·0	4,920	304·0	4,688	312·0	2,956	179·9
Sp. Gr. at 15·5°C	1·047		1·133		1·052		1·150	

No. 1. Overflow from casing-head of No. 1 well, Athabaska Oils, Ltd., Athabaska river. (Sec. 1, tp. 96, range 11.)

No. 2. Overflow from casing-head of "Salt of the Earth" well. Drilled by A. von Hammerstein, on west bank Athabaska river. (Lot 12, McKay settlement, tp. 95, range 11.)

No. 3. From largest spring at La Saline lake. (Sec. 15, tp. 93, range 10.)

No. 4. Overflow from casing of well drilled by Fort McKay Oil and Asphalt Company, at La Saline, August, 1913. (Sec. 15, tp. 93, range 10.)

Clays

Apart from clays referred to in Mines Branch Bulletin No. 10 (1915), other samples which were secured during 1924, have been examined by L. P. Collin, Ceramic Engineer, Mines Branch.

Sample No. 1. (Sec. 14, tp. 89, range 9.)

The sample was taken from Clearwater, Pit 1. It is a light brown clay and was quite plastic, but rather stiff when tempered with 26 per cent water.

Briquettes were moulded and burned at 1,742°, 1,886° and 1,994° F. The drying shrinkage of the briquettes averaged 6·5 per cent.

The clay fused at cone 8 (about 2,354° F.).

The briquette burned at 1,742°F. was a pinkish buff in colour, and was rather soft. At 1,886°F. the test piece was steel hard, and a pinkish brown in colour. At 1,994°F. it was steel hard and dark brown. All three of the briquettes showed a little scum on the edges. This clay might be used for common brick or tile, and if the colour were popular it could be used for wire-cut face brick. It is possible that it could be used for sewer pipe.

Sample No. 2. (Sec. 17, tp. 91, range 9.)

The sample was a light grey, fine-grained clay, which was slightly plastic, but rather flabby when tempered with 23 per cent water.

The clay fused at cone 27 (3,038° F.).

The burned briquettes were a light buff in colour, and were all fairly hard, excepting the one burned at 1,742°F.

The high fusion point of this material places it in the class of a moderate-heat duty fireclay. However, it is scarcely plastic enough to be used for firebrick or fireclay shapes. If a plastic clay with a high fusion point could be found near this deposit, a mixture of the two would probably make very good fireclay products.

Sample No. 3. (Sec. 17, tp. 91, range 9.)

The sample was a dark grey clay which was fairly plastic and worked well when tempered with 24 per cent of water. The drying shrinkage of small briquettes averaged 8 per cent.

Fusion point, 2,336° F.

The burned briquettes were all a reddish buff in colour and those burned at 1,886° and 1,994°F. were steel hard.

This clay, having good working qualities and a low shrinkage, as well as the property of burning hard at a fairly low temperature, should make good wire-cut face brick. The colour is not very common but is quite pleasing. A lighter buff might be obtained by burning at a higher temperature. It might also be a good material for vitrified products as the absorption is quite low at a temperature far below the fusion point. However, further tests will be made in the near future to determine its value for such products.

Sample No. 4. (Firebag river; Sec. 10, tp. 100, range 8.)

The sample was taken on the west bank of Firebag river 17½ miles from the mouth and was a pinkish coloured clay, slightly calcareous, and quite plastic when tempered with 33 per cent of water.

Briquettes were moulded and burned at 1,742°, 1,886° and 1,994° F. The drying shrinkage of these test pieces was 6 per cent.

The clay fused at cone 16 (about 2,642° F.).

The briquette burned at 1,742° was a light pinkish buff in colour and was quite soft. At 1,886° the piece was steel hard and a little darker in colour. At 1,994° the briquette was steel hard and fairly dark red in colour. All the briquettes showed a considerable amount of scum.

The material might be treated to prevent scumming, and it could then be used for stock or face brick, and building or drain tile. It is also quite likely that it could be used for sewer pipe.

Sample No. 5. (Firebag river; Sec. 17, tp. 99, range 7.)

The sample was a grey, glacial clay, and was slightly calcareous. It was not very plastic when tempered with 21 per cent water. Briquettes moulded from this clay dried well, but showed some scum when dry. The drying shrinkage was 6·3 per cent.

Briquettes were burned at the temperatures given below:—

Temperature ° F.	Fire shrinkage per cent	Absorption per cent
1,742	0·0	20·0
1,886	1·7	16·9
2,030	5·7	....

The briquette burned to 2,030° F. was puffed, due to incompletely oxidized carbon, and the absorption was not determined.

When burned as high as 1,886° F., a fairly good reddish brown colour was obtained and the test piece was steel hard. At 2,030° F., the colour was darker and the test piece was nearing vitrification. Quite a heavy scum was developed in all of the burned test pieces. The clay fused at 2,174° F.

This clay would make a good soft-mud brick, and could be used for stiff-mud brick if burned as high as 1,886° F. The clay would require careful burning and a long oxidation period because of the carbon contained. It would not be of any value for stoneware as the temperature of fusion is too low and the vitrification range is too short. It has not sufficient plasticity to be used on the potters' wheel.

WEATHER CONDITIONS IN THE McMURRAY DISTRICT

The climate in the McMurray district during the spring, summer, and autumn is not unlike that of central Alberta. Winter weather is dry and healthful, and very similar to that which prevails in the Cobalt and Porcupine mining areas of northern Ontario. The snowfall is relatively light.

Reliable meteorological records have been kept at McMurray since 1920. These include daily readings of maximum and minimum temperatures for morning and afternoon, and also precipitation throughout the year.

The following table (Table II) has been furnished through the kindness of Mr. Cecil Potts, J.P., Police Magistrate and Meteorologist, McMurray.

TABLE II

Record of Precipitation at McMurray

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.
1920	Nil	10·00	Nil	4·50	0·02	8·11	0·65	Trace	1·27	Trace	4·22	Trace	0·85	Nil	1·42	Nil	3·83	Nil	1·61	Nil	Nil	3·70	Nil	13·20
1921	Nil	27·35	0·32	8·35	Nil	8·35	0·28	0·25	2·99	Nil	1·68	Nil	3·28	Nil	2·59	Nil	0·65	Nil	0·50	Nil	Nil	13·35	0·13	4·45
1922	Nil	17·00	Nil	7·50	Nil	13·35	0·01	9·50	3·41	Nil	2·03	0·25	3·10	Nil	1·37	Nil	1·66	Nil	1·81	4·70	0·03	16·00	0·45	9·05
1923	Nil	7·75	0·04	5·00	Nil	11·25	Trace	Trace	0·82	Trace	2·02	Nil	3·21	Nil	2·64	Nil	1·16	Trace	0·64	0·10	0·10	6·55	Trace	7·75
1924	0·05	5·00	0·35	2·65	Nil	12·00	0·36	2·35	0·31	0·25	1·67	Nil	4·29	Nil	3·69	Nil	0·69	2·25	0·07	11·00	0·08	6·25	0·05	9·60

R. : rainfall in inches.
S. : snowfall in inches.

Record of Temperatures at McMurray

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1920	33	−50	45	−36	51	−40	58	−27	82	24	82	34	89	37	88	30	79	27	73	10	52	− 3	29	−28
1921	17	−45	51	−39	51	−33	66	14	80	25	86	27	87	36	85	34	75	22	78	15	48	−23	42	−46
1922	45	−52	39	−46	55	−37	73	− 5	85	26	83	29	87	36	85	31	75	25	64	12	45	−24	18	−41
1923	25	−43	51	−49	49	−39	76	−23	83	15	91	32	89	34	80	34	83	20	80	0	60	−17	47	−46
1924	43	−52	48	−32	45	−16	80	−11	89	15	86	25	98	37	77	30	80	17	66	13	56	−16	49	−50

TRANSPORTATION AND COMMUNICATION

A standard gauge railway, known as the Alberta and Great Waterways, has been constructed from Edmonton to Waterways, immediately adjacent to McMurray, at the head of navigation on the Athabaska–Mackenzie system, a distance of approximately 300 miles. A weekly freight and passenger train service is operated between Edmonton and Waterways, and a tri-weekly service to Lac la Biche, the first divisional point north of Edmonton. The railway is controlled by the Provincial Government and is operated by a Commission.

A telegraph line is operated between Waterways and Edmonton by the Alberta and Great Waterways Railway. Another telegraph line is operated by the Dominion Government, between Edmonton and McMurray via Athabaska, Pelican, and House river. A weekly postal service to McMurray is also maintained.

As yet no steps have been taken to provide adequate transportation between McMurray and certain promising bituminous sand areas in townships 94, 95, 96, and 97. The logical location of a railway northward from McMurray, appears to be along the river bottom lands to the west of the Athabaska river. Apart from the river crossing near McMurray, and a cutbank in sec. 12, tp. 92, range 10, no serious engineering difficulties would be encountered. The distance across Athabaska river from shore line to shore line at low water (Oct. 20, 1923) from a point near the Hudson Bay Company warehouse (lot 27, McMurray townsite), is approximately 950 feet. The cost of a single track, 5-span, through steel bridge, having a clearance of 30 feet above low water (Elev. 791), and including concrete abutments and piers, would apparently not exceed $350,000.[1] Such an extension of the Alberta and Great Waterways railway would serve the Beaver River, McKay River, and Ells River areas. Connexion with certain promising areas lying to the east of the Athabaska—as on Steepbank river, and in townships 95, 96, and 97—could doubtless be arranged.

Ice usually breaks up on Athabaska river between April 15 and April 25, and the river remains open until early in November. Below McMurray, a minimum draft of 2 feet 6 inches can usually be depended on for at least four months of each year. It is believed that during the period of open navigation, specially designed towing-boats and scows could be operated at a reasonable cost.[2] At the present time stern-wheel river steamers and power-boats, with ample accommodation for passengers and freight are operated by the Northern Transportation Company, Northern Traders, Ltd., the Hudson's Bay Company, and the Alberta and Arctic Transportation Company, from end of steel at Waterways to northern points on the Athabaska-Mackenzie system.

[1] Of this amount, cost of superstructure is estimated at approximately $260,000.

[2] See reference to operations under somewhat similar conditions, of Kentucky Rock Asphalt Company. (Chapter IV, p. 161.)

TABLE III

(a) Distances[1] on Athabaska river between McMurray and Crossing of 26th Base Line.

	Miles		Miles
McMurray to—			
Poplar island	6·3	McDermot island	48·4
Stony island	10·7	Crossing of 25th base line	51·2
Poplar creek	14·8	Lafont island	51·7
Inglis island	15·1	Calumet river	53·2
Tar island	18·9	Wheelers	54·2
Steepbank river	22·5	Wheeler island	54·7
Crossing of 24th base line	23·7	Pierre river	56·1
Saline	26·1	Morrison island	57·0
Morton island	27·7	Eymundson creek	60·2
Beaver river	31·1	Eymundson's	62·2
Muskeg river	32·1	Sled island	65·4
Alexander island	33·5	Bird island	67·9
McKay river	34·5	Williscroft island	69·9
McKay (opposite H.B. Co.)	35·3	Lorna island	70·7
Haight island	37·2	Dalkin island	71·6
Ings island	39·3	Lobstick point	77·2
Ells river	45·6	Shott island	77·6
Tar river	46·8	Crossing of 26th base line	79·8

[1] Distances are measured from steamboat landing (river lot 8), McMurray, along steamboat channel (1924) passing on west side of McMurray island. Mileage of islands refers to point on steamboat channel opposite head of island.

(b) Distances along Athabaska river from Athabaska[1] to Steamboat Landing, McMurray, (River Lot 8).

—	Miles	Side taken by canoes	Side taken by scows	Total descent, feet	Length of rapid, miles
Athabaska to—					
La Biche river	37·8				
Calling river	47·3				
Pelican portage	112·3				
Pelican river	114·8				
Pelican rapid	118·3	right	left or right	12	2·0
Rapid	131·0				
Rapid du Joli Fou (including Driftwood, Major, and Wheel)	138·0	either	either	9	1·2
House river	150·2				
Deadman creek	157·5				
Loon river	159·8				
Grand rapid (and head of island)	160·0	portage	right	44	0·8
Little Grand rapid	161·0			10	2·0
Rapid	166·0			10	0·5
Point La Biche rapid	168·0			10	2·0
Buffalo creek	179·2				
Brûlé rapid	186·2	right	right	8	0·5
Boiler rapid	206·8	right	middle to left	25	3·0
Middle rapid	209·0	right	left	20	1·5
Long rapid	212·5	right	left	28	3·0
Crooked rapid	221·3	right	left	13	1·5
Rock or Stony rapid	222·0	right	left	12	1·5
Little Cascade rapid	224·0	left	right	10	2·0
Big Cascade rapid	226·0	left	right	7	1·0
Mountain rapid	237·0	left to right	left to right	8	1·0
Moberly rapid	242·0	left	left	3	0·2
McMurray (steamboat landing)	244·8				

[1] Formerly known as Athabaska Landing.

CHAPTER II

REVIEW OF RESULTS OF INVESTIGATION BY MINES BRANCH

Scope of Investigation

The work completed by the Mines Branch on November 1, 1924, may be very briefly summarized as follows:—

I. INVESTIGATION OF CHARACTER OF DEPOSIT OF BITUMINOUS SAND.

The general character of the deposit of bituminous sand over a large area has been studied. Sixty-three core samples and a large number of less accurately taken, though representative, samples have been secured from certain of the more important outcrops. These samples have been analysed, and the physical and chemical characteristics of sand and of associated bitumen determined. This information is sufficiently complete to satisfy those familiar with the technology and manipulation of solid and semi-solid hydrocarbons as to the general characteristics of the bitumen.

II. SURVEYS.

Topographical surveys of considerable areas adjacent to Athabaska river and its tributaries, have been completed. A number of East-West sections have also been prepared.

III. SHIPMENTS.

A number of shipments of bituminous sand, aggregating approximately 140 tons, have been shipped and utilized in connexion with demonstration and experimental work.

IV. DEMONSTRATION PAVING.

In view of persistent adverse criticism that has been directed against the proposed use of crude bituminous sand as a paving material, the practical value of such a demonstration is apparent and real.

V. RECOVERY OF HYDROCARBONS FROM CRUDE BITUMINOUS SAND.

A study has been made of a number of processes designed for the recovery of various hydrocarbons from the crude bituminous sand.

I. INVESTIGATION OF CHARACTER OF DEPOSIT OF BITUMINOUS SAND

General Description and Extent of Deposit of Bituminous Sand

During the past twenty years, many statements have appeared regarding the extent and probable economic importance of the McMurray deposit. Liberal estimates of area and of average thickness were usually accepted, and the calculated tonnage commercially available was, of course, large. In arriving at this conclusion, three important factors were usually overlooked: (1) transportation; (2) variation in quality of material; and (3) overburden.

As regards transportation, it is obvious that a large part of the area underlain by bituminous sand will, for a long period, remain quite inaccessible to development. Moreover, in many parts of the area, it has been found that the bituminous sand is of such a low grade, as to be of little or no value. Lastly, and assuming that all excavation must take the form of open-cut work, the overburden becomes a factor of dominant importance. Even taking these three features into consideration, there still remains a large tonnage of bituminous sand commercially available.

It appears unnecessary—nor is it at present possible—to attempt a definite estimate of the area underlain by bituminous sand.[1] The writer has measured and examined more than 300 individual outcrops, all of which represent portions of an apparently continuous deposit. These outcrops extend along Athabaska river and its tributaries, through a total distance of more than 260 miles. The direct distance in a north and south direction, through which outcrops have been noted, is approximately 115 miles, and that from east to west approximately 55 miles. The total area underlain by bituminous sands is thus large. Probable extensions of the deposit under heavy overburden—particularly toward the south—will materially increase the above estimate.

EXTENT OF DEPOSIT

In Clearwater valley, the eastern limit of the bituminous sands has not been determined. Outcrops having an exposed thickness of approximately 70 feet, occur near the mouth of Cottonwood creek, notably in the S.W. ¼ sec. 5, tp. 89, range 5.[2] Much of the bituminous sand there exposed appears to be of low grade and of doubtful commercial value and the overburden is heavy. On the other hand, no bituminous sand was observed on High Hills river which enters Clearwater river from the north near the northeast corner of tp. 89, range 4. Thus it appears that the eastern limit of the bituminous sand in Clearwater valley occurs in range 4. Important outcrops of bituminous sand, much of which is of excellent quality, occur on Firebag river in tp. 97, range 6, and tp. 98, range 7[3]. In tp. 100, range 4, on the south branch of Reid creek—a tributary of Marguerite river—a cliff of rather coarse-grained bituminous sand, at least 75 feet in thickness, was noted. From levels secured on Cottonwood creek, Clearwater, Steepbank, Firebag, and Marguerite rivers, it is evident that, in passing eastward from Athabaska river, elevations of the base of the bituminous sand indicate a marked rise.

The northern limit of the bituminous sand has not been accurately defined. Where observed, however, the main body of bituminous sand appears to terminate somewhat abruptly against modern lake deposits,

[1] Besides deposits of bituminous sand in the McMurray area other occurrences in the province of Alberta have been reported near Bonnie Glen (N.W. ½ sec. 14, tp. 47, R. 27 W. of 4th mer.); Nakamun (N.E. ¼ sec. 28, tp. 56, R. 2 W. of 5th mer.); Legal (sec. 28 and 32, tp. 57, R. 25 W. of 4th mer.); Westlock (S.E. ¼ sec. 5, tp. 60, R. 26 W. of 4th mer.); on the farm of Jos. Trofoli, (N.E. cor. sec. 31, tp. 56, R. 2, W. of 5th mer.), and elsewhere. At none of these localities has bituminous sand been found in commercial quantity, although it is only fair to say that as yet no systematic prospecting has been seriously undertaken. The deposits are, however, so situated that no great outlay would be required to finally determine their commercial value.

At present they are here referred to merely as easily accessible and typical examples of a type of occurrence that appears to have a fairly wide distribution. In the opinion of the writer they are not "in place," and are therefore of little economic value. This conclusion has been arrived at after carefully examining such imperfect evidence as is at present available at the various localities mentioned.

[2] Unless otherwise stated all land subdivisions referred to in this report are west of the 4th meridian.

[3] In areas where subdivision surveys have not been undertaken, sections, townships, and ranges have been projected from stadia-compass traverses.

and suggests an erosional margin. In these lake deposits bituminous sand has, to some extent, been re-deposited in the form of minor partings. On Buckton creek the occurrence of major exposures of bituminous sand has been reported[1] in tp. 103, range 11. On Athabaska river, the most northerly major exposures occur in secs. 16 and 22, tp. 98, range 10, in the east and west banks respectively; on Firebag river, in sec. 22, tp. 98, range 7. As noted above, the most easterly major exposure, observed east of Athabaska river, is in tp. 100, range 4. It is probable, therefore, that a line passing through these four points, may approximate a portion of coast line or margin of an ancient lake basin, now partly occupied by lake Athabaska.

Marginal Deposits

Within the margin of the ancient basin toward the north, no outcrops of the main body of bituminous sand were observed on Marguerite river or on Firebag river, but along Athabaska river occasional minor exposures recur at intervals as far as township 105. The heavy bed of bituminous sand which, to the south of township 98, rises from elevations at or near river water level, is replaced by beds of recent (Quaternary) formation, consisting of sands, gravels, and clays. Near the top of these, is a stratum of bituminous sand, averaging from 2 to 5 feet in thickness, and having a well-defined contact with relatively light overburden. The underlying marginal deposits of sands, gravels, and clays, in places, show marked evidence of false bedding. Where sediments underlying the capping of bituminous sand consist chiefly of clean sand, many thin partings of bituminous sand, from 2 to 5 inches in thickness occur. The thicker and more continuous of these are largely unaltered bituminous sand, but thinner and interrupted partings, particularly in the lower strata, consist of non-cohesive, leached-out fragments. Interbedded between these partings are sand strata, varying in colour from reddish brown to light grey, and entirely unimpregnated by bitumen. (Plates III and IV).

Although cutbanks are marked by wide variation as regards preponderence of sand, gravel, or clay, and in the number of bituminized partings, a typical descending section is as follows:—

Overburden (sand and gravel)	4 feet
Bituminous sand (content in bitumen, 15 per cent)	4 "
Clean and well-defined contact	
Dry reddish sand (unimpregnated)	6 inches
Smooth plastic clay (pinkish colour)	3 "
Unimpregnated sand (light grey in colour) with 3 thin interrupted partings of leached out particles of bituminous sand	2 feet
Clean sand and gravel showing marked false bedding	5 "
Unimpregnated sand with 11 partings of bituminous sand (maximum thickness 4 inches)	21 "
Smooth plastic clay	35 "

Between the 26th and 27th base lines, cutbanks consist largely of sand and clay, and interbedded with these are bands of bituminous sand and bituminous sand-conglomerate.[2] Exposed thickness of such bands

[1] Not confirmed by writer.

[2] At a number of points on Athabaska river and on Firebag river (as in sec. 5, tp. 98, range 7), smooth rounded pebbles, having a maximum diameter of 6 inches, but with an average diameter of 2 inches, are associated with bituminous sand strata. At times the pebbles almost entirely replace the bituminous sand, forming a conglomerate cemented together with bitumen.

shows marked variation within narrow limits, but rarely exceeds a maximum of 15 feet. Typical descending sections are as follows:—

Sec. 23, tp. 101, Range 9 (East side Athabaska river)

Overburden (sand)	3 feet
Bituminous sand	4 "
Plastic clay (pinkish colour)	
Bituminous sand	10 "
Water level Athabaska river.	

Sec. 34, tp. 101, Range 9 (East side Athabaska river)

Overburden (sand)	6 feet
Bituminous sand	3 "
Sand with thin interbedded partings of bituminous sand (maximum thickness 3 inches)	11 "
Plastic clay	70 "
Water level Athabaska river.	

Tp. 104 (near Brûlé point) (West side Athabaska river)

Overburden (sand)	3 feet
Bituminous sand and bituminous sand-conglomerate	14 "
Gravel	11 "
Bituminous sand and bituminous sand-conglomerate	4 "
Water level Athabaska river.	

Genesis of Deposit

Pending completion of topographical mapping and other preliminary investigations, the possible genesis of the deposit has not been seriously studied by the writer. The following comment is therefore based on somewhat casual observation.

Strata immediately but unconformably underlying the bituminous sand, consist of Devonian shales, the character of which has not been definitely determined, and of highly fossiliferous limestone. (Plate V). Where well-exposed, the limestone comprises hard massive bands[1] alternating with rubbly and highly argillaceous strata. From available drilling records, many of which must be considered as unreliable, it appears that the limestone contains many cavities, large and small, and in certain of these, pure, semi-liquid bitumen is found. Thus, for example, in a well drilled in September, 1924, by A. von Hammerstein, in sec. 17, tp. 89, range 9, bitumen was encountered at a depth of 42 feet. Natural gas, which in one instance blew water to a height of 70 feet above the casing-head, has also been encountered during drilling operations at a number of points within the McMurray area. Minor seepages of gas indicated by bubbles on the surface of the water have been observed at two points between McMurray and Firebag river, and at the mouth of Little Buffalo river (sec. 2, tp. 86, range 18).

	A	B
CaO	48·31	42·44
MgO	2·68	3·74
Fe_2O_3 & Al_2O_3	1·54	2·74
SO_3	0·16	0·17
Insoluble mineral matter	5·90	11·46
Equivalent to		
$CaCO_3$	86·21	75·78
$MgCO_3$	5·60	7·81

[1] Analysis of two representative samples of limestone taken by the writer are given above. Sample "A" is from east shore Athabaska river in sec. 17, tp. 89, range 9; Sample "B" is from east shore Athabaska river in sec. 28, tp. 89, range 9.

Typical section of marginal deposit on Firebag river.

Typical section on north bank of Steepbank river, showing low-grade banded bituminous sand overlying well-stratified Devonian limestone.

As a result of minor folding on the main structure, slight, vertical fracturing of the limestone immediately below its contact with the overlying bituminous sand, is seen in some places. One of these fracture planes excavated by the writer, rapidly decreased in width, and finally terminated at a depth of 22 feet. Frequently such fracture zones are marked by infiltration of bitumen, or are partially or completely filled by the bituminous sand itself. Possibly pockets of bitumen in underlying limestone may also be due to downward seepage.

If, however, it is assumed that the residual bitumen has been derived from an asphaltic base petroleum, possibly originating in underlying Devonian strata, it seems probable that the inflow has been a horizontal one, rather than an upwelling at many points over a large area. If such is the case, the enrichment of the deposit would vary from the main inlet or inlets toward the outer margins of the basin, an assumption which appears to be borne out by actual conditions. It also seems probable that the folding of the Devonian strata was developed prior to the impregnation of the McMurray formation. This assumption, if correct, may prove of importance in determining the position of the more enriched portions of the area, and in explaining the genesis of the asphaltic residuum. Minor variation in the physical character and chemical composition of the associated bitumen is, of course, to be expected, since the original petroleums would themselves probably vary somewhat from point to point over so extensive an area.

The Cretaceous sediments overlying the bituminous sand, consist chiefly of dark shales with occasional thin interbedded sandstones. In drilling through these, small flows of gas have been encountered at different depths, but it appears probable that the gas has originated chiefly in the underlying bituminous sand.

It is thus difficult, from information at present available, to indicate the probable source of petroleum which has saturated sands of the McMurray formation [1] having an estimated aggregate volume of more than 500 billion cubic yards. To saturate this sand, would require crude petroleum having a volume equivalent to at least 50 billion cubic yards. It appears doubtful whether this could have originated in present immediately overlying Cretaceous, or in immediately underlying Devonian sediments. The possibility that the petroleum originated in overlying petroliferous shales, subsequently removed by erosion, appears remote.

With reference to the marginal deposits referred to above, as bordering the northern limit of the main body of bituminous sand (Plates III and IV), it is probable that these were laid down under changing climatic conditions. Thus toward the close of the Glacial period, somewhat low temperatures probably prevailed, and consequently eroded particles and masses of bituminous sand did not readily soften and consolidate as compacted strata, although partial leaching out of the bitumen by circulating cold waters would be effective. Subsequently the effect of higher temperatures and correspondingly warmer waters, appears to have been reflected in later and more compacted secondary deposits. The

[1] As a result of recent studies, F. H. McLearn, of the Geological Survey, considers that the bituminous sands are earlier than Dakota, and therefore the use of the name Dakota should not be continued. Provisionally, the bituminous sands are here referred to as "McMurray formation."

principal band of bituminous sand, which occurs near the top of the marginal sediments, is well-compacted, and in places is marked by what appears to be a flow structure.

In an article entitled "Peculiar Phases of Oil Saturation in Certain Sandstones,"[1] Glen L. Ruby discusses certain features presented by "oil sands" of the Uinta Basin, Utah. In part, the article is as follows:—

North of the Book Cliffs, along the outcrop of the Green River sands the saturation is most prominent. The outcrop has such extent and the sands appear so continuous that it was rather to be expected that many recommendations for drilling would be made. However, it appears that in most cases only brief notice was taken of the sand. Saturation was noted and probably accounted for in the regular manner, it being assumed that since the Green River formation contained oil shales, the sands had acquired the oil from this source, although the oil shales lie several hundred feet above the sand series which is associated with practically barren shales. . . .

The material constituting the formations was the result of erosion of domal land masses still subject to upwarping movements. This same orogenic folding was likewise responsible for the retention of the Tertiary waterbodies. Older formations, especially Upper Cretaceous and Pennsylvanian, which were involved in the folding are known to be oil-bearing in this region and some of the oil undoubtedly migrated into these geanticlines and was permitted to escape by continued erosion. In many of these domal areas erosion progressed rapidly and all sedimentaries were removed so that later Tertiary beds rest unconformably on the granites.

Surface drainage from the surrounding land transported clastic material for the Tertiary beds. Streams from areas of doming and oil accumulation must have at times carried variable amounts of oil, depending on the size of the reservoir tapped by erosion or leakage to the surface permitted by faulting. It cannot be disputed that large quantities of oil were transported by surface drainage into the Tertiary lakes, where this drainage was off a doming land mass involving oil-bearing formations subject to erosion.

A careful examination of present-day streams in which oil is escaping will explain the occurrence of oil-filled cavities in a sandstone or conglomerate. Many such streams exist in the western United States and similar conditions may be found in streams flowing through oil fields and tank farms where basic sediment is allowed to escape into surface drainage. There are several oil seepages along Tow creek, in northwestern Colorado, and it was along this stream that "oil rolls" were first observed by the writer.

Fresh oil escaping from this seepage floats for a time on the water and as the more volatile constituents are lost by evaporation the mass sinks and is rolled along by the current. It assumes a spherical form or becomes a short cylinder, depending upon stream action. If entrapped in an eddy it soon rolls into a perfect sphere, but if rolled steadily forward by the current it becomes cylindrical. It was noted that farther from the seeps these rolls became more viscous and some several miles below the source, were found to have the consistency of damp clay. Observations made over a period of three years showed the stream bed to be practically free from "oil rolls" after a flood, while during the period of steady flow every "hole" in the creek was practically floored with oil.

This oil, being carried along with sand and clay, must ultimately be deposited with it and the manner of its deposition depends upon the manner and amount of the oil escaping into the stream and the distance it must be transported. . . .

Where oil has escaped in large quantities, as might be expected when erosion permitted the first burst of oil to escape from some reservoir, there would be a constant flow down the stream and into the lake or sea. If this oil should become sufficiently heavy to sink in the stream it would still flow into the sea and be spread out in much the same manner as other sediments. It would be closely associated with the sediments in which it originated and which came into the sea as worked-over material in the same drainage. It would also be more or less mixed with these sediments, depending upon the relative amounts of oil, water, and sediment that

[1] Bulletin of the American Association of Petroleum Geologists, Vol. VII, No. 5, 1923.

the stream carried. On the other hand, if it floated out onto the surface of the lake or sea its final destination would depend upon currents and the direction of prevailing winds. In this manner, a sheet of oil or asphaltum might be deposited in clays or fine sands and not associated with the sediments carried by the stream which also carried the oil.

The deposit of bituminous sand in the McMurray area constitutes the largest known occurrence of solid asphaltic material. Marginal deposits towards the north are correspondingly extensive. It is evident that this northern area will furnish an excellent opportunity for the study of this type of deposit.

Well Records

During the past 20 years, a number of wells have been drilled within the McMurray area, and many inquiries have been received by the writer regarding results obtained. Although recorded logs of certain of the wells are of doubtful value as accurate records, nevertheless they furnish information regarding general stratigraphical conditions. The following notes comprise a summary based on the writer's own information, supplemented by such records as are available on Departmental files at Ottawa. In view of the attention that is now being directed to the McMurray area, and since even the location [1] of many of the wells drilled will soon be forgotten, it is considered that a summarized statement will be of value as a convenient reference.

Well No. 1 (Elevation approximately 1650).—Drilled between May 14, and September 1, 1918, in S.E. ¼ sec. 26, tp. 83, range 6, to a depth of 1,076 feet, by J. R. Talpey of Los Angeles, Cal. It is stated that neither gas nor oil was encountered.

Well No. 2 (Elevation approximately 1550).—Drilled by the Northwest Company, Ltd.,[2] in 1918, on the S.W. ¼ sec. 27, tp. 85, range 7.

The following is a statement of the log as reported by the company:—

—	Thickness feet	Depth feet
Gravel	10	0—10
Clay	30	10—40
Sand and shale	365	40—405
Water at 60 feet.		
Salt water at 293 feet.		
Hardstreak	5	405—410
Shale	55	410—465
Hardstreak	3	465—468
Gas at 468 feet, 150,000 cu. ft.		
Sandy shale	12	468—580
Soft brown shale	30	580—610
Tar sand	90	610—700
Gas at 620 feet.		
Tar and water at 656 feet.		
Blue shale	8	700—708
Hardstreak	7	708—715
White running sand	24	715—739
Water at 715 feet.		
Shale	9	739—748
White lime rock	72	748—820
Water at 763 feet.		

[1] Among wells here referred to, the exact locations of No. 13, No. 15, and No. 16 are not known to the writer.
[2] Subsidiary of the Imperial Oil Co., Ltd.

Well No. 3 (Elevation approximately 1320).—Drilled in September and November, 1917, by the Northwest Company, Ltd., on S.W. ¼ sec. 33, tp. 87, range 7. The following is a statement of the log as reported by the company:—

—	Thickness feet	Depth feet	—
Drift	80	80	
Clay shale	90	170	Water—20 bbl. per hour; shut off with 10-inch casing.
Sandy shale	1½	171½	
Clay shale	151½	323	Hard-shell at 269 feet.
Sandy seam	....	323	50,000 cu. ft. dry gas.
Clay shale	90	413	
Tar sand	63	476	Water at 475 ft.; rose 80 ft. and not lowered by bailing.
Limestone	28	504	Shut off with 8-inch casing.

Well No. 4 (Elevation 823).—Drilled by Provincial Government, province of Alberta, in 1922-23, in L.S. 5, sec. 32, tp. 88, range 8.

The following is a summarized statement of the log[1]:—

0— 40 feet. Overburden.
40—415 " Limestones and shales.
415—782 " Limestones and shales, with anhydrite, gypsum and salt lenses and cavities.
785— " Contact between Devonian and Precambrian.
789— " Bottom of well.

No beds of pure rock salt were passed through, but many thin and unworkable lenses of salt were cut. At a depth of approximately 670 feet, a flow of salt water was encountered.

Well No. 5 (Elevation 790).—Drilled by Provincial Government, province of Alberta, in 1921, in river lot 8, McMurray settlement. The following is a summarized statement of the log[2]:—

0— 60 feet. Overburden and Recent deposits.
60—500 " Limestones and shales.
500—627 " Limestones, shales, anhydrite and gypsum.
627—685 " Anhydrite, gypsum, and 20-30 feet of rock salt.

Wells Nos. 6-10[3].—Drilled by Northern Alberta Exploration Company, prior to 1913, in L.S. 6; sec. 17, tp. 89, range 9. Log records of these wells appear to be of doubtful value, but it is evident that strata passed through consist chiefly of limestones, shales, and an undetermined thickness of saline deposits.

Well No. 11 (Elevation 826).—Commenced by A. von Hammerstein, in 1924, in L.S. 6, sec. 17, tp. 89, range 9. In September, 1924, this well had reached a depth of 47 feet. The log, as reported, is as follows:—

0—24 feet. Overburden.
24—38 " Limestone.
38—39 " Bitumen, (pure and semi liquid).
39—47 " Limestone.

[1] For complete log see Fourth Annual Report, Scientific & Industrial Research, Council of Alberta, 1923.
[2] For complete log see Second Annual Report, Mineral Resources of Alberta, 1920.
[3] In 1924 the Alberta Salt Company of Edmonton undertook the installation of equipment for recovery of salt from brine pumped from certain of these wells. A plant having an initial capacity of 25 tons per day was placed in commission in 1925, and a considerable tonnage of excellent salt has already been marketed.

Well No. 12 (Elevation 1041).—Drilled by Northern Alberta Exploration Company in 1914, in L.S. 14, sec. 9, tp. 89, range 9.

0— 27	feet.	Overburden.
27—100	"	Soapstone (probably Clearwater shales).
100—210	"	Sandstone containing some oil (possibly bituminous sand).
210—221	"	Bituminous sand.

Well No. 13.—Drilled on east side Athabaska river " about 2 miles north of mouth of Clearwater river " in 1908. The following is a summary of the log as reported to the Department of the Interior.

0— 78	feet.	Bituminous sand, with thin strata of almost pure bitumen.
78—233	"	Shales and limestones. Showing of gas at 60, 150, and 165; showings of bitumen at 146 and 171 feet.

Well No. 14 (Elevation 812).—Drilled by A. von Hammerstein in L.S. 14, sec. 8, tp. 90, range 9, on east bank Athabaska river.

The following summarizes the log records as filed with the Department of the Interior, in 1909:—

0— 38	feet.	Overburden.
38— 109	"	Grey and brown limestone. At 72 feet, small gas pocket.
109— 150	"	Shales. At 120 feet, small flow of gas.
150— 465	"	Limestones and shales. Flow of gas at 321 feet, and at 417 feet.
465— 505	"	Sandstone, with some gas.
505— 796	"	Limestone, with some gas.
796— 829	"	Brown limestone, with evidences of petroleum.
829—1,010	"	Limestones and shales.
1,010—1,117	"	Precambrian rocks.

Well No. 15.—Drilled by A. von Hammerstein about 1908 on east side of Athabaska river, approximately three-quarters of a mile below Poplar island. The following is a summary of the log as reported to the Department of the Interior.

0—740 feet. Limestones and shales; saline water at 658 feet; bitumen at 90, 215, 525 and 541 feet; showing of gas at 145, 320 and 440 feet.

Well No. 16.—Drilled by A. von Hammerstein, approximately one-quarter of a mile north of Stony island, on east side of Athabaska river, about 1907. The following is a summary of the log as reported to the Department of the Interior:—

0— 20	feet.	Overburden and bituminous sand.
20— 73	"	Sandstone with some rich bituminous sand.
73—446	"	Limestones and shales. A flow of gas at 293 feet, and limestone saturated with petroleum or bitumen at 420 feet.

Well No. 17 (Elevation 790).—Drilled by A. von Hammerstein in 1906-7 in L.S. 3, sec. 6, tp. 92, range 9. Strata passed through consisted chiefly of limestones and shales, with pockets or strata of bitumen. Two gas horizons were encountered but flow of gas was negligible. During 1909-10, the well gave a small flow of brine.

Well No. 18 (Elevation 822).—Drilled by A. von Hammerstein about 1907, in L.S. 13, sec. 7, tp. 92, range 9. The following is a summary of the log as reported to the Department of the Interior:—

0— 25	feet.	Bituminous sand.
25—321	"	Shales and limestones; thin strata of almost pure bitumen at 18, 80 and 273 feet. Small flow of gas at 260 feet. Saline water at 325 feet.

Well No. 19 (Elevation 896).—Drilled by A. von Hammerstein in 1907-8, in L.S. 15, sec. 19, tp. 92, range 9. The following is a summary of the log as reported to the Department of the Interior:—

0— 10	feet.	Overburden.
10— 12	"	Stratum of almost pure bitumen.
12— 36	"	Rich bituminous sand.
36—110	"	Sand and sandstone, with one stratum of almost pure bitumen.
110—950	"	Shales and limestones. Gas indications encountered at 635, 645, and 680 feet; saline water at 730 feet; showing of petroleum at 645 feet.

Well No. 20 (Elevation 779).—Drilled by Fort McKay Oil and Asphalt Co., in 1912-13, in L.S. 10, sec. 15, tp. 93, range 10. The reported depth of the well was 1,080 feet. A good flow of gas was reported, but no oil.

Well No. 21 (Elevation 798).—In L.S. 14, sec. 7, tp. 94, range 10. In 1909 this well was spudded in but was never drilled.

Well No. 22 (Elevation 777).—Drilled by F. Violette in L.S. 15, sec. 24, tp. 94, range 10, about 1910.

Well No. 23 (Elevation 791).—Drilled by A. von Hammerstein, river lot 12, McKay settlement (tp. 95, range 11) in 1907. This well reached a depth of 615 feet, when cable broke. Drilling-tools are still in the well. Strata passed through consisted of limestones and shales. During 1908-9, a small flow of gas was given off, but since 1909, the well has given a small flow of saline water, highly charged with sulphur compounds.

Well No. 24 (Elevation 780).—Drilled in L.S. 6, sec. 35, tp. 95, range 11. Drilling equipment was installed in 1917, by Wm. Parker, Manager of the Tekoa Athabaska Oils, Ltd., but no actual drilling was performed by him. Subsequently, in the same year, drilling was completed to a depth of 123 feet by J. D. Tait and P. von Auberg. The log showed 14 feet of overburden, underlain by dark brown bituminous sand. Jetting was resorted to in passing through the bituminous sand, but one hard band, two feet thick, was drilled by the use of standard tools. No gas or oil was encountered.

Wells Nos. 25, 26, 27, 28, 29.—Drilled by J. D. Tait, Athabaska Oils Ltd., in 1915. Logs given are summaries of information furnished to the Department of the Interior.

Well No. 25 (Elevation 816).—Drilled in L.S. 8, sec. 2, tp. 96, range 11.

Well Log—

0— 4	feet.	Overburden.
4— 18	"	Cemented oil sand.
18— 78	"	Bituminous sand.
78— 98	"	Shale.
98— 155	"	Bituminous sand.
155— 957	"	Limestones, shales and gypsum.
957—1,030	"	Hard reddish flinty rock.

At 765 and at 1,000 feet, flows of salt water were encountered.

Well No. 26 (Elevation 878).—Drilled in L.S. 5, sec. 1, tp. 96, range 10.

Well Log—

0— 3	feet.	Overburden.
3— 8	"	Bituminous sand.
8— 62	"	Shale.
62—210	"	Bituminous sand.
210—	"	Shale.

Well No. 27 (Elevation 913).—L.S. 12, sec. 1, tp. 96, range 10.

Well Log—
0— 10 feet. Overburden.
10—175 " Bituminous sand.

Well No. 28 (Elevation 925).—Drilled in L.S. 14, sec. 1, tp. 96, range 10.

Well Log—

0— 10	feet.	Overburden.
10— 58	"	Shale.
58—172	"	Bituminous sand and shale.
172—176	"	Cap rock.
176—262	"	Brown or black bituminous sand.
262—282	"	Shale.

A strong flow of gas was reported at 58 feet.

Well No. 29.—Drilled in sec. 1, tp. 96, range 10. The following is a summary of the log as reported.

0— 4	feet.	Overburden.
4— 69	"	Shale.
69— 77	"	Oil sand (bituminous sand?).
77—167	"	Shales and sand impregnated with bitumen or heavy petroleum.
167—177	"	Oil sand (bituminous sand?).

Well No. 30 (Elevation 993).—Drilled by Alcan Oil Co. in 1921, in L.S. 13, sec. 28, tp. 96, range 10. The following report was submitted by the company in October, 1921.

Surface 68	feet.	Wash and loose sand.
68— 75	"	Tar sand with water.
75—155	"	Tar sand very soft.
155—170	"	Black shale and some oil.
170—205	"	Black shale with show of oil.
205—218	"	Oil sand with oil water and show of gas.
218—238	"	Oil sand, no water (water above).
238—245	"	Very soft sand, water at top and heavy viscous black oil flows slowly into hole.

Drilling was discontinued at 245 feet, as the oil in the hole was too viscous for drill to work and bailer would not penetrate into it more than a foot. The casing gradually moved down into the sand and now extends to a depth of 262 feet. The oil has filled into pipe for 100 feet and the bailer will not penetrate over two feet. When taken from the hole the oil thickly covers the tools and bailer and drips off slowly in long ropy masses. The water encountered always lies in the upper few feet of sand; it is fresh and undoubtedly is seeping surface water. Drilling will be continued when difficulties are overcome.

No gas encountered.

Bitumen or tar at 68-75′; 75-155′; 155-170′; 170-205′; 205-218′; 218-235′; 245-262′ heavy slow-flowing asphaltic oil.

	Water encountered	Rose to	How shut off
1st sand	From 0-68′	Fresh....flowed	8″ casing
2nd sand		" 150 ft.	6″ casing
		" 150 ft.	Not shut off.

Well No. 31.—Drilled by Alcan Oil Co., in 1922, in L.S. 14, sec. 24, tp. 96, range 10. Elevation 1037. The following report was submitted by the company in October, 1922.

	Formation
0— 2 feet.	Surface
2— 72 "	Water sands.
72—103 "	Clay, no sign of oil.
103—120 "	Coarse oil sands.
120—145 "	Fine oil sands with thin oil.
145—165 "	Clay with oil sand mixed in.
165—167 "	Undefined.
167—265 "	Oil sand.
265—270 "	Oil sand with very heavy oil.
270—335 "	Fine oil sand.
335—357 "	Clay with oil showing.
357—369 "	Fine oil sand, very rich in oil.
369—411 "	Clay with oil in it.
411—440 "	Oil sand, shale pyrites.
440—450 "	Oil sand, shale (brown).
450—481 "	Oil sand, shale.
481—549 "	Oil sand.
549—555 "	Black shale.
555—560 "	Clay, with water, ran into hole. Impossible to go on with hole without casing.

Gas Encountered

	Approximate Amount	How shut off
1st sand 167-168′	5,000 ft.	6¼″ casing
2nd sand at 430′	Very light	Not shut off

Oil encountered, depths. 103-145′; 167-335′; 357-369′; 411-450′; 481-549′.

	Water Encountered Rose to	How shut off
1st sand 2-72′ fresh	Surface	8″ casing
2nd sand 120-145′ fresh	100′	6¼″ casing
3rd sand 555-560′ fresh	300′	Not shut off

Well No. 32 (Elevation 757).—Drilled by the Athabaska-Spokane Company in 1917, in L.S. 6, sec. 1, tp. 97, range 11.

This well was drilled by jetting to a depth of approximately 105 feet. Five feet of overburden was passed through and approximately 100 feet of rich bituminous sand.[1] Drilling was commenced at 8 a.m. October 20th, and was completed at 9 p.m. of the same day. A 6-inch bit was used but the well was not cased.

Well No. 33, (Elevation 780).—Drilled by J. D. Tait for the Northland Oil Syndicate in July 1918, in L.S. 15, sec. 13, tp. 97, range 11. The log of the well shows 12 feet of overburden and approximately 68 feet of bituminous sand, resting on what appeared to be clay or argillaceous limestone.

The log has been summarized as follows:—

0–12 feet.	Sandy soil.
12–80 "	Bituminous sand.
80–96 "	Clay.

[1] During July and August, 1925, Mr. R. C. Fitzsimmons of Edmonton drilled a well near the shore of Athabaska river, approximately 580 feet south of well No. 32. Drilling was commenced at an elevation of approximately 766 feet and discontinued at an elevation of approximately 630 feet. With the exception of a 5-foot band of rather low-grade material encountered at an elevation of approximately 636 feet, only minor partings of bituminous sand were found. Such a result forms a striking contrast with conditions met with in well No. 32.

Well No. 34 (Elevation 858).—Drilled by Mr. Rodarmel for the Northland Oil Syndicate in September 1918, in L.S. 2, sec. 24, tp. 97, range 11. The log of the well shows approximately 5 feet of overburden and 60 feet of rich bituminous sand.

The bottom of this well was "sprung" by the use of 12 pounds of dynamite, after which low pressure steam was introduced. It is said that, at the end of 12 hours, a mixture of sand, water and liquid bitumen, was discharged to a height of 25 feet above the casing-head. Steam was then turned into the well for a further period of 18 hours, after which a quantity of the sand-water-bitumen mixture was removed by use of the sand bailer. This mixture was then pumped to a storage tank, when partial settling of sand and water was effected. The log has been summarized as follows:—

0–4 feet.	Sandy overburden.
4–64 "	Oil sands.
64–72 "	Clay.

Showings of bitumen or heavy petroleum are reported at various elevations.

OTHER WELLS DRILLED WITHIN TERRITORY ADJACENT TO THE McMURRAY AREA

Wells Nos. 35 and 36.—Drilled by Northern Production Co., Ltd., (succeeded by Edmonton-Athabaska Oil, Ltd.), at intervals during 1914, 1916, 1917, 1918 and 1921, in sec. 30, tp. 83, range 16. The first of these two wells was abandoned at a depth of 200 feet. The second was drilled to a reported depth of 665 feet and it is stated that considerable flows of gas estimated at 3,000,000 cubic feet per day were encountered.

A summary of log of well No. 35 is as follows:—

0–16 feet.	Overburden.
16–415 "	Sandstones and shale (with gas at 265, 340, 353 ft.)
415–665 "	McMurray sands, underlain by Devonian limestones and shales.

Wells Nos. 37 to 41.[1]—Wells 37, 38 and 39 were drilled on the west side of Athabaska river, in sec. 31, tp. 78, range 17, and wells 40 and 41, on the east side of Athabaska river in sec. 32, tp. 77, range 17, by the Pelican Oil and Gas Company and the Calhoun Oil Company between 1912 and 1915. These wells are commonly referred to as the "Pelican wells". Reference to wells 38 to 41 is based on a report submitted in 1922 by Mr. S. E. Slipper to Mr. O. S. Finnie, Director, Northwest Territories Branch.

Well No. 37.—Drilled in sec. 31, tp. 78, range 17, by Mr. W. A. Fisher on behalf of the Geological Survey of Canada, in 1897. According to Dawson[2], the bituminous sands appear to have been reached (nearly as anticipated), at about 750 feet, and penetrated to a depth of nearly 70 feet. Maltha or heavy, tarry petroleum was here met with, saturating the sands and shales in a manner similar to that found in the same lower Cretaceous

[1]Samples of the gas were secured in 1924 by R. T. Elworthy, Mines Branch, Ottawa.
[2]Summary Report, Geological Survey Department, 19A, vol. X, 1897.

beds where they outcrop farther down the Athabaska. At 820 feet, an exceedingly heavy flow of natural gas under great pressure was struck, such as to prevent for the time being any further work in the hole.

The strata passed through in drilling the above well, may be summarized as follows:—

0–86	feet.	Sand and gravel (overburden).
86–185	"	Dark bluish-black soft shales, with some sandstone in upper part. (Pelican shales).
185–465	"	Greyish sands and sandstones, brownish and greyish shales. (Grand Rapids sandstones).
465–750	"	Greyish and brownish shales, alternating with thin beds of hard sandstone and ironstone. (Clearwater series).
750–820	"	Sands and clays often saturated with heavy oils and bitumen (bituminous sand).

The following are summaries of logs as furnished by the Pelican Oil and Gas Company, Ltd. It will be observed that, in some instances, these are incomplete.

Well No. 38—

0– 18	feet.	Overburden.
18– 78	"	Dark blue shale and a little gas.
78–290	"	Shales and thin bed of "shell."
		Sand and water; gas blowing water to crown of derrick.
290–385	"	Shales; boulders at 327.
385–425	"	Dark sticky shales showing a little oil and asphalt.
425–497	"	Shales and sand; thin bed of "shell."
497–498	"	Gravel and water.
498–533	"	Sticky shales.
533–750	"	Shales, sandstone and sand; with thin beds of "shell;" strong flow of gas at 550–552; gas and odour of petroleum at 575–630.
750–765	"	Brown shale.
765–778	"	Shale showing bitumen.
778–781	"	Limestone "shell."
781–840	"	Shales.
840–845	"	Sandy shale with increasing flow of gas.
845–868	"	Fine brown sand with increasing flow of gas.
868–872	"	Fine brown sand; gas very strong.

Drilling discontinued at 872 feet on July 30, 1914.

Well No. 39—

0– 60	feet.	Overburden.
60– 90	"	Live water sand.
90–375	"	Shales; shell at 352-355.
375–378	"	Bituminous sand.
378–764	"	"Shell" with 2 feet of sandstone.
803	"	Strong odour of petroleum.
803–819	"	Ironstone nodules and showing of heavy oil.
892–903	"	Hard formation.
936–1005	"	Limestone and sandstone.
1018	"	Gas with showing of oil.
1038	"	Gas with odour of sulphur.
1070	"	Gas with strong odour of sulphur.
1070–1560	"	Limestone, shale and "shell;" strong odour of petroleum 1537–1560.
1560–1800	"	Shale with hard bands of "shell;" some gas with strong odour of sulphur, 1611-1641.
1800–1825	"	Sticky blue shale.
1825–2023	"	Limestone.
2023–2126	"	Shales; showing of gas 2090-2102.
2126–2131	"	Limestone.
2131–2420	"	Shales with bands of limestone.

Drilling discontinued at 2420 feet, April 25, 1914.

Well No. 40—

0– 60	feet.	Overburden.
60– 90	"	Live water sand.
90–334	"	Shales with interbedded "shell."
334–350	"	Bituminous sand, rich in gas.
350–652	"	Shales with interbedded "shell."
652–659	"	Soft sandstone with bitumen.
659–832	"	Shales with interbedded "shell." Gas at 715 and 800.

Large flow of gas from fine-grained, brown dry sand.
Drilling discontinued at 832 feet on March 25, 1913.

Practically no gas was given off in 1922. Either this well was not drilled to the gas sand, or the gas was cased off.

Well No. 41—

0– 34	feet.	Overburden.
34–625	"	Shales with thin interbedded sandstones and "shell;" showings of gas at 98, 235, 250, 280, 350, 485, 405, and 624; showings of oil or bitumen at 350, 405.
625–693	"	Sand with shale partings; strong odour of petroleum and heavy flow of gas.
693–828	"	Shales with interbedded "shell;" gas at 730 and 794; bitumen at 778 and 794.
828–937	"	Limestones and sandstones, grey to almost black in colour.
937–970	"	White porous limestone with showings of bitumen.
970–1062	"	Limestones and sandstones; small showing of gas at 980.
1062–1070	"	Lime shale with pocket of gas.
1070–1101	"	Limestone.

Drilling discontinued on January 10, 1915.

In 1922 the well showed a flow of gas estimated at 4,600,000 cubic feet, under approximately 300 pounds pressure.

General Subdivisions of Bituminous Sand Area

For convenient reference, waterways along which bituminous sands occur, may be divided into three sections. These subdivisions are purely geographical, and are not based on considerations presented by the deposit of bituminous sand.

Section 1. Athabaska river, Boiler rapids to McMurray; approximate length, 42 miles.

Section 2. Athabaska river, north of McMurray; approximate length, 76 miles.

Section 3. Streams tributary to Athabaska river; approximate length, 143 miles.

Section 1

Athabaska River: Boiler Rapids to McMurray

In descending Athabaska river, from Athabaska, the first outcrop of bituminous sand is observed just above Boiler rapids on the west shore (township 87, range 14), although bituminous sand float was found some 4 miles farther up stream. At the former point the valley of the Athabaska is over 400 feet deep; valley walls, for the most part, rise steeply from the water's edge. As such conditions implied a prohibitive thickness of overburden, no samples were secured, nor were any actual measurements taken between this point and Big Cascade rapids. Throughout this distance of upwards of 18 miles, bituminous sand continues along both sides of the river, though actual outcrops are as a rule obscured.

Such exposures as do occur are frequently highly banded, and much of the bituminous sand itself is low grade. This is due to the fact that the lower and richer part of the deposit is obscured by a rapidly rising gradient of the river bed[1] and a slight southerly dip of the bituminous sand strata.

Between the foot of Big Cascade rapids and McMurray, a number of exposed sections were examined. Here, as elsewhere, owing to talus piles, clay slides, and drift, difficulty was experienced in determining the lower limit of the bituminous sand, as well as the upper limit at which the material ceases to be of commercial grade. Although samples were taken from only one of the outcrops examined, it appears probable that in nearly all, beds of bituminous sand of workable size and of commercial quality will be found[2]. (Plates VI and VII.) Serious difficulties are presented by heavy overburden and absence of disposal ground for same, and by considerations affecting transportation. It should, however, be remembered that these outcrops are usually found at the outer edge of river bends, where the stream has cut back into the higher ground, and has thus exposed high sections that necessarily show a heavy overburden. It is possible that careful study of the less abrupt topography of the ground lying between such outcrops may, if accompanied by systematic borings, result in the discovery of workable deposits. In view of the more favourable conditions under which bituminous sand is found elsewhere in the McMurray district, exposures referred to in Section No. 1, with possibly one or two exceptions, should not be seriously considered at the present time.

Section 2

Athabaska River north of McMurray

Along Athabaska river, north of McMurray, forty-eight separate outcrops of bituminous sand were noted. Although all represent portions of one continuous deposit, there is marked variation in quality of material,

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[1] Approximate fall in Athabaska river between—

22nd base line and 23rd base line (dist. 82 miles)	411 feet
23rd base line and McMurray (dist. 5·5 miles)	22 "
McMurray and 24th base line (dist. 22 miles)	23 "
24th base line and 25th base line (dist. 27 miles)	20 "
25th base line and 26th base line (dist. 27 miles)	15 "

[2] Tonnage of bituminous sand for various areas and thicknesses. Specific gravity of bituminous sand taken as 1·75. Short tons of 2,000 lbs.

Thickness in feet	Tons on 1 acre	Tons on 2 acres	Tons on 3 acres	Tons on 4 acres	Tons on 5 acres
1	2,380	4,800	7,100	9,500	11,900
5	11,900	23,800	35,800	47,700	59,600
10	23,800	47,700	71,600	95,400	119,200
15	35,800	71,600	107,300	143,100	178,905
20	47,700	95,400	143,100	190,800	238,500
25	59,600	119,300	178,900	238,500	298,200
30	71,600	143,100	214,600	286,200	357,700
35	83,500	166,900	250,400	333,900	417,400
40	95,400	190,800	286,200	381,600	477,000
45	107,300	214,600	321,900	429,300	536,600
50	119,200	238,500	357,700	477,700	596,300

Typical exposure of bituminous sand near Big Cascade rapids (sec. 1, tp. 88, range 12). The overburden is very heavy and no disposal ground is available.

Outcrop on east side of Athabaska river (sec. 2, tp. 89, range 10). Although the thickness of the bituminous sand exceeds 150 feet, the overburden is heavy.

and in conditions which affect commercial development. From present knowledge, based on surface examination only, it appears that among the more promising areas, the following may be mentioned: sec. 28, tp. 89, range 9; secs. 6 and 7, tp. 90, range 9; sec. 20, tp. 91, range 9; secs. 19 and 30, tp. 92, range 9; secs. 7, 8, 17 and 18, tp. 95, range 10; secs. 26 and 35, tp. 95, range 11; secs. 23 and 26, tp. 96, range 11; sec. 32, tp. 97, range 10; secs. 12, 13, and 24, tp. 97, range 11; secs. 9 and 11, tp. 98, range 10.

Section 3

Streams Tributary to Athabaska River

Apart from exposures of bituminous sand along Athabaska river, frequent outcrops occur on the following more important tributary streams.

Name of stream	Approximate distance through which outcrops occur	Approximate number of outcrops
	miles	
Clearwater river	31	2
Christina [1] river	10	23
Hangingstone river	4	16
Horse river	5	15
Poplar creek	3	10
Steepbank river	11	34
Beaver river	13	26
Muskeg river	9	17
McKay[2] river (and Osier creek[3])	23	68
Ells[4] river	18	74
Tar river	3	13
Calumet creek	2½	10
Firebag river	22	40

[1] Formerly Pembina river.
[2] Formerly Little Red river.
[3] Formerly Willow creek.
[4] Formerly Moose river.

Nearly all of the above streams are of the meander type. They have eroded deep notch-like valleys, along the bottom of which wind shallow water-courses. In ascending them, swift currents and almost continuous light rapids are met with during the first few miles. At high or even medium stages of water, such sections may usually be navigated by canoes,—but rarely at low water. However, as the general level of the surrounding country is approached, the water deepens, the current becomes slack, and navigation easier. It may be added that, owing to the topographical nature of the valleys, these streams are quickly affected by heavy rains; and after such, may for a few days even at periods of low water, become occasionally navigable for canoes, by poling and tracking.

Well-defined terraces constitute a notable feature of river bottom lands, whether of large or small extent. These terraces would appear to indicate the boundaries of residual deposits of bituminous sand, but, unfortunately, this is not always so. Where, however, residual bituminous sand underlies a terrace, the maximum thickness of the bituminous sand is usually found in an upstream direction.

Horse River

Through townships 88 and 89, Horse river flows in a deep, trough-like depression that is much older than the relatively small channel that at present winds along its bottom. The effective erosive force in this valley was, however, never equal to that of the Athabaska. Consequently, in the case of the Athabaska, north of Long rapids, there is, to-day, a river channel cut completely through the bituminous sand and into the underlying Devonian limestone. The stream that eroded Horse River valley has, at only two points, cut down to the base of the bituminous sand, and as a consequence, the floor of the present valley in township 89 is, for the most part, made up of bituminous sand. Into this floor a diminishing flow of water has cut its way, and in receding to its present channel, has left a series of residual areas of bituminous sand. (Plate VIII.)

With the exception of McKay River, Ells River, and Clearwater River valleys, bottom lands along Horse river are more extensive than those of any of the other tributary streams. Consequently, within the loops of its tortuous channel, areas of a few acres are found. Along the margins of certain of these bottom lands, erosion has exposed low faces of residual bituminous sand overlain by light gravel and other river wash. In other cases, the bituminous sand has been eroded almost to present water level, and has been replaced by sand and gravel.

Thus, on Horse river—and other tributary streams in the McMurray district—there are two types of deposits of bituminous sand:—(Figure 1.)

(*a*) *Low-lying deposits, outcropping to a height of 5 to 30 feet, immediately along the present channel.* These exposures represent such small residual areas of bituminous sand as still remain in the original valley bottom, and have a relatively light overburden. (Plate IX.)

(*b*) *Exposures at points where the stream has impinged against the sides of the main valley.* Such exposures, in general, resemble those already referred to in Section No. 1, along the Athabaska, and exhibit a thick section of bituminous sand under a heavy overburden. (Plate IX.)

In 1914 portions of sections 5 and 8, township 89, bordering on Horse river, were selected by the writer as a reserve for the National Parks Branch, Department of the Interior. During the course of a somewhat detailed examination of this reserve, 20 test pits were sunk through the overburden, and test borings made in the underlying bituminous sand. Analyses of 32 of these core samples indicate that in uniformity of sand aggregate and in percentage of associated bitumen, the Horse River reserve comprises one of the most promising fields in the McMurray area.

A detailed, topographical map of the reserve was also drawn on a scale of 1 inch equals 200 feet, and contours at 10-foot intervals were indicated. Estimates of apparent tonnage of bituminous sand available were then prepared, together with corresponding yardage of overburden to be removed, should commercial development be undertaken.

For convenient reference, the Parks Branch Reserve has been subdivided into sub-areas, A, B, C, D, and E, and pending the completion of further borings, the following provisional table of quantities has been prepared.

Margin of residual deposit of bituminous sand under light gravel overburden on Horse river (L. S. 15, sec. 5, tp. 89, range 9).

Exposures on east and west sides of Horse river, (L. S. 15, sec. 8, tp. 89, range 9). On the right is seen a typical residual deposit under light overburden lying within a loop of the stream. On the left (where the stream impinges against the concave bank) a complete section of the bituminous sand is seen under heavy overburden.

Area	Bituminous sand	Overburden
	tons	cu. yd.
A	719,000	294,000
B	107,000	75,000
C	130,000	115,000
D	1,700,000	1,557,000
E	705,000	1,145,000
Total	3,361,000	3,186,000

The difficulties in the way of surface transportation along Horse river are those common to most tributary streams in the McMurray district. At alternate bends in the stream, where the current impinges against the banks, the possibility of slides must be taken into consideration. Points opposite such cutbanks are, however, usually low and free from the effects of slides.

The most promising areas on Horse river are in secs. 5, 8 and 17, tp. 89, range 9.

Clearwater River

Clearwater river is the largest stream entering Athabaska river north of Athabaska. Between McMurray and the mouth of Christina river, the width of the stream varies from 100 to 200 yards. The main slopes of the valley usually lie well back from the present stream channel, and in a distance of 20 miles[1] above the mouth, only two exposures of bituminous sand were seen in the river bank. Numerous small exposures in tributary ravines, at elevations quite 125 feet above river level, indicate the continuation of a heavy bed of bituminous sand.

In the principal outcrop (L.S. 4, sec. 14, tp. 89, range 9), the bituminous content, as well as the grading of the mineral aggregate, shows considerable variation, but at present it is impossible to express any opinion as to the probable value of the upper and concealed portion. However, two miles to the northwest, the extension of this outcrop, exposed in high cutbanks along Athabaska river, shows a material of which the average is apparently below commercial grade. (Plate X, page 36.)

As already noted, well-defined terraces have been observed in the river bottoms of certain streams. These terraces consist either of bituminous sand or of river wash. Certain of them occur immediately adjacent to the grade of the Alberta and Great Waterways railway in the Clearwater valley, and should they prove to consist of bituminous sand, would be of immediate commercial importance.

Three of these terraces in Clearwater valley were selected, and test pits sunk to a depth of 15 to 30 feet. In no instance was bituminous sand encountered. It is the opinion of the writer that certain of these terraces may consist, in part at least, of bituminous sand, although the general directness of the lower Clearwater valley would probably preclude the occurrence of extensive residual deposits.

[1] All distances are measured along the actual stream channels.

Hangingstone River

The deep, notch-like valley of Hangingstone river is narrower than that of Horse river, and with one notable exception in sec. 9, tp. 89, range 9, the area of occasional bottom lands rarely reaches 5 acres. Consequently, the sides of the valley rise, as a rule, almost from water's edge, and heavy clay slides are frequent, particularly where fire has destroyed the forest growth.

Along the first 5 miles of the river, bituminous sand outcrops at nearly every bend. One mile above the mouth, the lower limit of the deposit is near water level; but owing to the rapid change in elevation in ascending the stream, the exposed thickness of the bituminous sand rapidly decreases. As the general elevation of the country on either side is approximately 300 feet above water level, the significance of overburden, even near the mouth of the river, is apparent.

In 1913, an interesting sub-variety of bituminous sand was observed by the writer on Hangingstone river. The best exposure occurs near the upper part of the first outcrop on the west bank (L.S. 12, sec. 9, tp. 89, range 9). The material consists of silica sand, silt, and freshwater shells, the richer and more massive portions being cemented together with a soft bitumen. The leaner, well stratified bands constitute a hard, calcareous sandstone almost free from bitumen, and contain a profusion of well preserved fragments of plants and forest growth and freshwater shells.

In a sample of the richer material the proportion of each constituent was determined as follows:—

	Per cent
Sand (90 per cent of which passes a 50 mesh, and is retained on a 200 mesh)	64·7
$CaCO_3$ (present in form of freshwater shells)	20·3
Bitumen	15·0
	100·0

The bed referred to above is lenticular in form and has an observed maximum thickness of approximately 12 feet. The available tonnage of the richer material does not appear to be great, while its variable character renders it of doubtful commercial value. A descending section arbitrarily selected is as follows:—

	Feet thick
Overburden	45
Low-grade bituminous sand (dry and banded)	22
Bituminous sand carrying shells	5
Low-grade bituminous sand (banded)	33
High-grade bituminous sand	70
	175

In ascending Hangingstone river, above this outcrop, pieces of similar shell-bearing float were found for upwards of 1¼ mile.

Special applications of the material have not as yet been determined. It is, however, probable that it would form a satisfactory basis for asphalt mastic.

Christina River

The Christina river, which enters the Clearwater 18 miles to the east of The Forks at McMurray, was ascended a distance of 16 miles. Along its lower course the average width of the stream is probably 400 feet, narrowing to less than 200 feet at 15 miles from the mouth. Light rapids occur at frequent intervals during the first 10 miles.

The general elevation varies from approximately 400 feet, near the mouth, to approximately 460 feet above stream level at 10 miles from the mouth, and, as the breadth of the valley diminishes, depth of overburden and heavy clay slides become more and more controlling factors in considering the possible development of areas of bituminous sand. As in many other parts of the McMurray district the effect of forest fires is marked, although small areas of spruce and poplar still remain in the valley bottom. Where fire has swept to the water's edge, the increased instability of the banks is at once apparent (Plate II). Saline springs and small seams of lignite, some of which are of commercial importance, were noted at a number of points.

Deposits of bituminous sand recur throughout a distance of 10½ miles from the mouth of the river. For some three miles, low-lying and typical Devonian limestones underlie the bituminous sand, but beyond this point the limestone disappears altogether.

Topographically, the valley of the Christina river resembles that of Horse river. Its course is, however, more direct and the small areas of bottom lands are consequently few. In all, 23 exposures of bituminous sand were noted, 7 of which were examined in detail. Owing to heavy overburden, prevalence of clay slides, and the presence of impure partings in the bituminous sand, it was considered that the remaining 16 could be eliminated from further consideration. Considering overburden, difficulties of transportation, and character of much of the bituminous sand, areas along Christina river do not appear adapted to commercial development at the present time. A notable exception may be mentioned in sec. 22, tp. 88, range 7. Here topographical conditions are highly favourable, but extensive sampling of outcrops by means of asphalt augers, although inconclusive, indicated that much of the bituminous sand is not of commercial grade. A somewhat limited residual deposit on the west shore in sec. 7, tp. 88, range 6, could be easily developed, and might warrant the expenditure necessary to provide transportation.

Steepbank River

Steepbank river is a swift, shallow stream, and enters the Athabaska from the east, 22·5 miles below McMurray. The width at the mouth is about 100 feet, narrowing to 80 feet at 17 miles. The depth of the valley decreases from about 250 feet at 2 miles, to about 220 feet at 10 miles. A trapper's trail, which is somewhat difficult to follow, leaves the Athabaska at the mouth of the Steepbank, and follows up along the north shore as far as the forks.

For 5 miles from the mouth of the river, well-bedded Devonian limestones, showing in places traces of bitumen, undulate along the

shores at elevations varying from 5 to 40 feet. Resting on the limestone, sections of bituminous sand are exposed on the outer bank at nearly every bend, the richer and more homogeneous grade underlying the drier and more banded material. In ascending the stream, and following the disappearance of the limestone, the sections of bituminous sand also gradually begin to disappear, so that beyond mile 10, little, except low-grade material, remains exposed above water level.

Apart from considerations of transportation, which is at present entirely undeveloped, certain areas adjacent to Steepbank river, (notably in secs. 20, 21 and 29, tp. 92, range 9) appear to have real merit from the viewpoint of commercial development.

Beaver River

Beaver river, a swift, shallow stream, enters Athabaska river from the west 31·1 miles north of McMurray. It is unnavigable for canoes, and has a width which rarely exceeds 40 feet. A trapper's trail leaves Athabaska river, in L.S. 1, sec. 7, tp. 94, range 10, and parallels Beaver river for a distance of more than 8 miles.

Owing to marked folding, and possibly faulting, Devonian limestones are well exposed for a distance of 2¾ miles from the mouth, and in places attains a thickness of at least 90 feet. Ledges of limestone, dipping toward the southwest, are also seen within the northern portion of the triangle lying between Beaver river and Athabaska river, all bituminous sand having been eroded from this area. These ledges represent the harder limestone strata. Rubbly and more argillaceous interstratified bands have been partly eroded, and are represented by minor depressions and narrow wet areas roughly parallel with the strike.

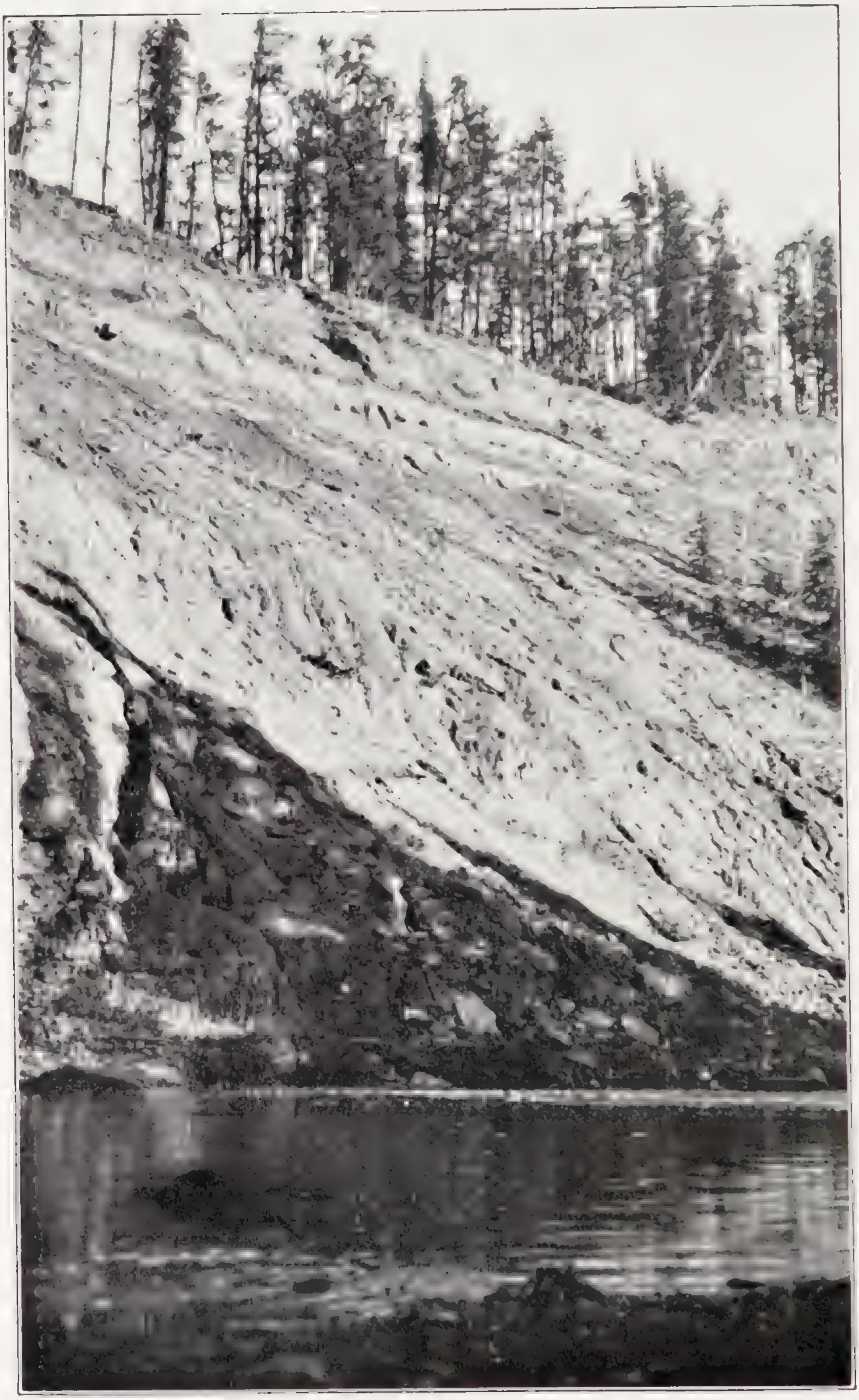
Owing to the general southwesterly dip, limestones are not seen on Beaver river beyond a point approximately three miles from the mouth. From here, cliffs of bituminous sand, having a maximum exposed thickness of 105 feet, recur throughout a distance of 10 miles. Although much of the material seen along the northern portion of the river is apparently of good quality, owing to a rising stream gradient together with a southerly dip, the lower and richer beds gradually disappear, leaving only the upper and more banded beds exposed.

Conditions along the northern portion of Beaver river (notably in secs. 25, 26, and 36, tp. 93, range 11), are unusually favourable to commercial development of bituminous sand. Apparently the overburden is light (Plate XI) and easily removed, moreover an ample area is available for disposal grounds and other purposes. Toward the headwaters in townships 91 and 92, Beaver River valley is marked by long, easy clay slopes which in part appear well adapted to agriculture.

Muskeg River

Muskeg river enters Athabaska river from the east at a point 32·1 miles north of McMurray. Its width near the mouth is approximately 100 feet, decreasing to 60 feet at 5 miles, and to 30 feet at 15 miles.

Exposure on east bank of Athabaska river 3 miles below McMurray, illustrating the typical banded character of the lower grade bituminous sand.



Exposure of bituminous sand on east bank Beaver river, under light sand and gravel overburden, (L.S. 10, sec. 25, tp. 93, range 11). In the lower left hand corner, limestone is seen dipping steeply toward the southwest.

Throughout this distance the stream is navigable for canoes at high and medium stages of water, but beyond, log jams and other obstacles render navigation increasingly difficult, or altogether impossible.

The first 6¼ miles consist of a series of rapids necessitating continuous and somewhat difficult poling and tracking. An Indian portage, 1¾ mile in length, leaves Athabaska river 2 miles below the mouth of Muskeg river, and meets that stream at the head of swift water. Beyond this point the portage may be followed as far as Muskeg lake. Another portage leaves Athabaska river, in sec. 31, tp. 94, range 10, and meets Muskeg river somewhat higher up.

In ascending Muskeg river, ledges of both massive and rubbly limestone, 10 to 75 feet high, are exposed for nearly 5 miles. At a number of points minor infiltrations of bitumen along bedding and joint-planes are seen.

Occasional small exposures of bituminous sand recur to within a short distance of the crossing of the north boundary of township 94. Of these, apparently the most promising occurs in the northwest bank about 1¼ mile above the head of the portage, and extends along the stream for quite 400 feet (Plate XII). The average exposed thickness is 15 feet and it is overlain by a thin capping of quartzite. Moreover, at a number of points within the triangle lying between Muskeg and Athabaska rivers, bituminous sand is seen at or near the surface. It appears that parts of this area (notably in secs. 18, 19 and 29, tp. 94, range 10) are of sufficient promise to warrant further detailed exploration.

McKay River

McKay river is one of the most important tributaries entering the Athabaska, north of McMurray. Its width near the mouth is about 175 feet, narrowing to about 100 feet at 18 miles. Throughout the first 26 miles, a series of light rapids is met with, but by means of poling and tracking, canoes may be taken up at medium stage of water. Beyond 26 miles the current slackens, and navigation becomes easier.

The river flows through a narrow valley marked by precipitous slopes and high cutbanks. At 3 miles from the mouth, the average depth of the valley is approximately 220 feet, decreasing to 150 feet within the next 15 miles. The surface of the country on either side is gently undulating, with low sandy knolls and ridges, and large areas of swamp and muskeg. The greater part of the country has been burned over, and is now covered by second-growth timber.

For some distance above the mouth, the usual well-bedded, grey and buff, highly fossiliferous limestones are seen. These strata rise and fall in a series of minor folds, sections with a maximum height of 90 to 100 feet being thus exposed.[1]

Above the limestones, sections of bituminous sand are exposed throughout the first 22 miles. In places, examples of differential denudation

[1] At a number of points on McKay, Muskeg, Steepbank, and other streams, bitumen is seen associated with Devonian limestone. This bitumen is apparently derived from overlying bituminous sand. Where the limestone is of a rubbly nature, or where shattering has accompanied the development of a line of weakness in the more massive strata, fragments of rock have become more or less heavily coated with bitumen. In certain instances bitumen has also filled minor cavities in the rock.

(Plate XIV) are seen where bituminous sand has been eroded from above the harder underlying limestone. In such cases, the bituminous sand will nearly always be found a short distance back from the river, though usually obscured by moss and forest growth. As elsewhere, the richer portion of the bituminous sand, in nearly every instance, directly overlies the limestone, whereas the upper portions of the beds become leaner and banded with interstratified partings. Thus, when the limestones, with an apparent general dip toward the southwest, disappear near mile 14, the exposed sections of bituminous sand thereafter become lower, until finally near mile 22 only the upper or banded zone remains above water level.

In all, some 68 exposures of bituminous sand were seen on McKay river and on Osier creek, and from 9 of the more representative of these, accurate core samples were taken in 1914. Certain of the above outcrops represent a large tonnage of good quality material. It appears that the most promising areas occur in secs. 19, 23, 29 and 32, tp. 94, range 11.

Transportation to Athabaska river presents the usual difficulties met with along the valleys of streams of this character, and if the deposits are developed, the road would follow the more direct route across the high ground lying back from the valley.

Ells River

Ells river enters Athabaska river from the west, at a point 45·6 miles north of McMurray. The average width near the mouth is about 150 feet, decreasing at 16 miles to 100 feet. The stream is navigable for light canoes at medium stages of water, although numerous light rapids necessitate poling and tracking.

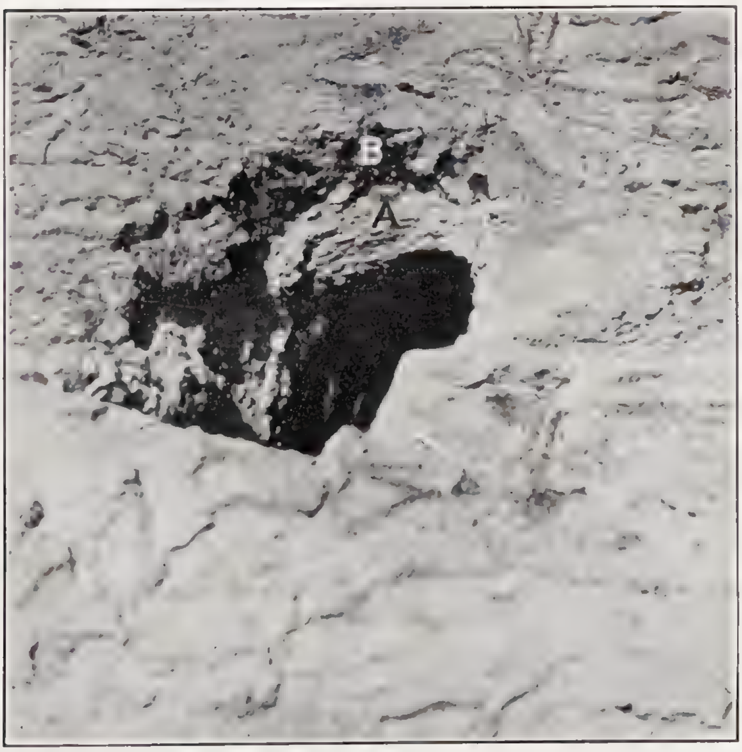
The valley is for the most part narrow. The general country elevation varies from 180 to 200 feet above water level, throughout the first 15 miles. At a number of points, however, changes in the course of the river have resulted in the formation of occasional lateral basins and low-lying areas, which may prove of importance should development of the bituminous sand be undertaken. An Indian trail from McKay to Moose lake crosses the river above the more difficult of the rapids, and between this point and the mouth, a distance of approximately 14 miles, 74 outcrops of bituminous sand were noted. Limestone in place was seen at one point about 8 miles from the mouth. Here, the crest of a local fold extends along the north shore for several hundred feet, attaining a maximum elevation of 8 or 10 feet above water level. Above the trail crossing, outcrops of bituminous sand recur for at least 4 miles, but most of the material exposed is banded and of low grade.

With certain minor exceptions, bituminous sand exposed along the stream below the mouth of Canning creek (mile 4), is of low grade, and of a distinctly banded nature. This corresponds with the character of material exposed along the lower portion of Tar river to the north, and on Athabaska river immediately to the northeast and east. Again, beyond mile 9, a similar deterioration is noticeable. Consequently detailed exploration should be directed to the area lying between the mouth of Canning creek and mile 9. The triangle lying near the junction of Canning creek and Ells river, presents topographic conditions favourable to large-

Plate XII

Exposure on northwest bank Muskeg river (L.S. 4, sec. 29, tp. 94, range 10). At outcrop, material is of comparatively low grade, but overburden is light.

Plate XIII



A tunnel started in rich bituminous sand, B, (sec. 14, tp. 89, range 9), passed at a depth of a few inches into a stratum, A, consisting largely of clay.

Typical example of differential denudation seen along the larger valleys.

scale commercial development. As on other streams of a similar nature, commercial transportation within the valley itself is practically impossible. Owing, however, to lighter overburden, clay slides are not a serious feature. It appears that the most promising areas occur in secs. 21, 27, 33 and 34, tp. 95, range 11.

Tar River

Tar river is a rapid stream, 20 to 30 feet wide, which enters Athabaska river from the west at a point 46·8 miles north of McMurray. For half a mile from the mouth, its course winds through a low-lying, well-timbered river bottom, but beyond this point, a rapid rise takes place, resulting in a series of almost continuous light rapids. The stream is not navigable for canoes.

The first exposure of bituminous sand occurs in the north bank, approximately 2 miles from the mouth. Other exposures recur during the next two miles. For the most part, however, exposed material is banded and of low grade, the maximum observed thickness of rich material being 18 feet. Owing to the rapid rise in the stream gradient, the lower and richer bituminous sand rapidly disappears, and in mile 4, only highly banded material and black, finely divided clay shales are seen. Trappers' trails parallel the river on both the north and the south sides, to a point well beyond the last of the exposures.

Calumet Creek[1]

Calumet creek enters Athabaska river from the west, at a point 53·2 miles north of McMurray. The valley near the mouth is 90 to 100 feet deep. The stream is seldom more than 15 feet wide, and rises rapidly for 1¾ mile. Beyond this point the valley broadens out, and the stream flows with sluggish current through a flat, swampy area bordering the lower slopes of Birch mountains.

Commencing at a point approximately half a mile from the mouth of the river, a number of outcrops recur during a distance of slightly more than one mile. Owing to the limited extent of exposures, it is difficult in some instances to accurately estimate their probable value. From surface indications, however, it appears that the greater part of the bituminous sand is much banded and of inferior quality.

A trapper's trail leading to Wolf lake, with branches to headwaters of Pierre river and Tar river, leaves the Athabaska at a point 300 feet north of the mouth of Calumet creek, and parallels that stream for 1½ mile.

Firebag River

Firebag river enters the Athabaska from the east, 1½ mile north of the 26th base line, or 81 miles north of McMurray. The average width near the mouth is about 300 feet, decreasing to 200 feet at 25 miles. The principal tributary, Marguerite river, enters from the east at mile 28·4.

[1] Locally known as Wolf creek.

At medium stages of water (as a rule until the middle of August), Firebag river is navigable for canoes for at least 60 miles. With the exception of 4 or 5 miles near the mouth, shores are well suited to tracking. Between mile $14\frac{1}{4}$ and the mouth of Marguerite river, six light rapids occur, of which the heaviest, Cascade rapids (mile $17\frac{1}{2}$), has a fall of approximately 1 foot in 100 feet. These rapids are caused by minor folding of Devonian limestones and dolomites. At a number of points jointed and rubbly limestones are stained or coated with bitumen. In no instance, however, can these be classed as a bituminous limestone, nor do they in any way resemble European rock asphalt.

Above the mouth of Marguerite river, the volume of water diminishes by nearly one-half, although at mile 60, Firebag river still has a width of 120 to 130 feet. Along this section of the river, numerous light rapids occur where limestones approach the surface or are actually exposed. Water level elevations increase from 736 feet at the mouth to 814 feet at Marguerite river, and to 1,168 feet at mile 60.

The country adjacent to the river consists of extensive sandy plains, broken by numerous gullies, and presents excellent examples of erosion forms. Numerous muskegs and sloughs occur where drainage is ineffective. There is ample evidence that, until quite recently, much of the area adjacent to Firebag river was covered by valuable forests of jackpine, with spruce in the lower ground. As a result of forest fires, however, the growth now consists very largely of small jackpine and poplar.

In ascending Firebag river, no exposures of bituminous sand are seen below the mouth of Marguerite river, although float is occasionally found. Excellent sections, which at times attain a thickness of 100 feet, show heavy beds of plastic, pinkish coloured clays overlain by uncompacted, stratified sand. Throughout this sandy strata, numerous thin, interrupted partings of bituminous sand occur, few of which exceed 3 inches in thickness. (Plate IV, page 18.)

The first actual exposure of bituminous sand in situ, occurs in the east bank, at mile 28·6, or approximately 1,100 feet south of the mouth of Marguerite river. At this point a ledge of rich material, exposed for a thickness of 4 to 6 feet, underlies 50 feet of clay and 40 feet of sand and gravel. At mile 33·8, a series of outcrops of bituminous sand commences, and continues to mile 55·9. Toward the northern margin of this series, gravels and sandy gravels completely impregnated with bitumen, are seen.[1] In all, 40 exposures of bituminous sand were noted, varying in thickness from 5 to 20 feet. Wide variation also exists in the character of the material, the richest and most promising areas apparently lying between mile 43·5 and mile 47·3 (secs. 4 and 5, tp. 98, range 7). At many points the overburden, consisting entirely of sand or of sand and gravel, is very light. Indeed apart from considerations of transportation, and having regard to richness of material and favourable conditions for mining, the writer knows of no area within the McMurray district that is better adapted to commercial development. The highest exposed elevation of bituminous sand (mile

[1] Similar beds of agglomerate or impregnated gravel, up to 14 feet in thickness, occur on the east side of Athabaska river in tp. 102, and on west side of Athabaska river in tp. 103.

55·9, sec. 31, tp. 97, range 6), is 1,130 feet, as compared with a corresponding elevation of 835 feet at a point approximately 30 miles due west on Athabaska river.

Like many other rivers tributary to Athabaska river Firebag is an excellent example of a meander type of stream and many extensive areas of river bottom lands occur within the loops. Although thin, residual beds of bituminous sand are common along the margins of such areas, it appears that the greater part of the bituminous sand has been eroded.

Marguerite River

Above the forks Marguerite[1] river is very similar to Firebag river and is navigable for canoes at medium stages of water. Navigation is interrupted at a number of points by light rapids, and log jams. These necessitate a number of short " carries " and portages, none of which exceed half a mile in length. A trapper's trail leaves Firebag river at a point about half a mile from the mouth, and extends eastward to the junction of Marguerite river and Reid creek.

Owing to lateness of the season, the writer did not ascend Marguerite river, but the character of the stream was observed at a number of points adjacent to the trail. Mr. W. Miller, of McMurray, states that no exposures of bituminous sand occur below the mouth of Reid creek, but cutbanks, at times more than 100 feet in height, consisting of typical clays, sands, and gravels, are seen. In range 5, occasional bosses of Precambrian granites and gneisses, usually of limited extent, rise to a height of 100 to 500 feet above the general level of the country.

The only occurrences of bituminous sand observed by the writer during a brief reconnaissance to the east of Firebag river, in October, 1924, are in township 100, range 4, on the south branch of Reid creek, the principal tributary of Marguerite river. On the north bank of the stream, two outcrops, of which the larger is 75 feet high and approximately 300 feet long, consist of a somewhat coarse sand, in which the bitumen content apparently does not exceed 8 per cent. On the other hand, coarse-grained bituminous sand, on weathering, loses its bitumen content more rapidly than do the finer aggregates, and it is therefore probable that richer material will be found at points somewhat removed from actual outcrops. It appears that these outcrops—which are said to recur throughout a distance of nearly 7 miles—represent portions of the sediments deposited between the Precambrian outliers noted above.

The country adjacent to Marguerite river and its tributaries, is very similar to that observed along Firebag river, the terrain being marked by the presence of many muskegs and sloughs with numerous small lakes and ponds.

Minor Streams

If workable deposits of bituminous sand are not found along rivers and creeks referred to above, it will be useless to look elsewhere in the McMurray area. Nevertheless a considerable number of smaller tributaries, many of them little more than brooks, were noted.

[1] Known locally as Cree river.

Small streams, such as these, not having any great erosive power, have a rapidly rising gradient, and usually reach general country level within 2 or 3 miles of their junction with the Athabaska. Consequently, the vertical dimensions of sections of bituminous sand exposed near their mouths, quickly decrease with the rapid change in elevation in ascending the streams. Moreover, although valleys of such creeks are usually mere notches, with no areas of bottom lands, the effect of clay slides is pronounced wherever fires have removed forest growth. If actual excavation were undertaken along any of these slopes, the effect of such slides would be greatly increased.

Other Occurrences

Apart from occurrences in the McMurray area referred to above, other exposures of bituminous sand occur at points many miles to the east and west, on Wabiskaw river, Alberta, and on Buffalo lake, Saskatchewan.

The writer has not had an opportunity of visiting the occurrences reported on Wabiskaw river—notably near the junction of the Prairie (or Pine) river with the Wabiskaw.[1] Information secured from a number of apparently reliable sources, appears to indicate conclusively that the bituminous sand is not in situ, and would therefore be of no commercial importance. Moreover, the distance from the mouth of Prairie river to rail transportation at Mirror Lake station, on the Edmonton, Dunvegan and British Columbia railway, is at least 110 miles, or rather more than 250 miles from Edmonton, the nearest large centre of population.

From time to time references have been made to deposits of bituminous sand at or near the Upper Narrows, Buffalo lake, Saskatchewan (township 79, range 19, west of the 3rd meridian). On both sides of the Narrows, small excavations were made by the writer in 1914, and former small excavations were also examined.

On the east side, only a few small fragments of bituminous sand float,—none over two pounds in weight—were found. These fragments were of poor quality, though evidently much altered by the action of water.

On the west side of the Narrows, what appeared to be low ledges of bituminous sand were found. A small amount of excavation showed these to be masses of float, the largest weighing possibly 5 to 8 tons. It is impossible to say whether the main body from which these were derived occurs nearby, or the bituminous sand has been transported a considerable distance. The appearance of the material is similar to that found in the McMurray area. Careful enquiry among the natives and fur-traders living between Methy portage and Ile-à-la-Crosse failed to elicit any information regarding other local occurrences.

For the most part the country to the east and west of Methy river, Methy lake, and Buffalo lake, is low-lying; and the infrequent and limited sections exposed, indicate the presence of a heavy blanket of glacial and post glacial material.

Everywhere there is a fairly heavy forest growth, consisting of poplar, birch, and spruce. To the west of Buffalo lake, the ground rises gradually. Buffalo river, the largest tributary entering from the west, was ascended

[1] Ponton. A. W., Survey of Fifth Meridan, 1908-9.

for some 28 or 30 miles, but no rock in place was seen. Under conditions such as the above, prospecting for bituminous sands in this area will be difficult. The direct distance from the Narrows to the present end of steel (Canadian National railway), at Big River, Saskatchewan, is approximately 165 miles.

Outlying deposits of bituminous sand similar to those noted above, warrant no serious consideration at the present time. If commercial development of the various outcrops, already recognized in the McMurray district, is found to be impracticable, it is evident that deposits such as those on Wabiskaw river and Buffalo lake, cannot be considered as of economic importance.

The writer's observations have not extended north of the 27th base line on Athabaska river. Other occurrences of bituminous sand are, however, reported from a number of areas lying many miles to the north and northwest, on Athabaska lake, Great Slave lake, and along the Peace River valley.

Detailed Description of Deposit of Bituminous Sand

Certain outcrops of bituminous sand south of township 99, represent portions of a deposit which under favourable market conditions, and with adequate transportation facilities, will eventually prove to be commercially valuable. But it is also true that the greater part of the area underlain by bituminous sands cannot be considered as of any present economic importance. (Plates VI, X.) In many instances it has been possible to definitely eliminate certain areas from further consideration as regards their present economic value, but, for reasons noted elsewhere, it is not at present an easy matter to definitely designate among the remaining areas those which will prove of greatest commercial value. Mere measurements of what are frequently imperfectly exposed vertical sections, cannot convey definite and reliable information, and indeed in many instances, must prove misleading. Tables of measurements of all the exposed sections in the McMurray area have been compiled, and an attempt has been made to estimate the thickness of bituminous sand of commercial grade; the thickness of what may be referred to as low-grade material—the greater part of which must probably be classed as overburden; and finally to determine the probable thickness and character of surface drift, shales, sandstones, and other overburden. For reasons noted above, these tables are omitted from the present report. Indeed it is quite possible that certain portions of the deposit, that are at present partly or wholly obscured, may, on examination, present advantages over certain other areas where outcrops are well-exposed at the present time, for exposures naturally occur at bends of the stream where the current, impinging against the outer shore, has caused the formation of cutbanks. So uniformly does this rule apply that given an accurate map of any of the streams flowing through the area underlain by bituminous sand, it is possible to indicate very closely those points at which outcrops of bituminous sand will be found. At such exposures, surface indications may also prove misleading as regards the character of the bituminous sand itself. Thus for example a coarse-grained aggregate weathers out much more rapidly than a fine aggregate, and an

outcrop that appears low in bitumen content, may rapidly improve even at shallow depths. In other instances, owing to the very gradual downward flow of bituminous sand from high-grade bands, very considerable thicknesses of low-grade material, heavy beds of interstratified clay, and the underlying limestone itself may become wholly obscured. An excellent example of such a flow is seen in the outcrop on the east bank of Clearwater river in sec. 14, tp. 89, range 9. (Plate XIII.)

At various points wide variation occurs in the quality, thickness, and character of the bituminous sand and of the overburden, and in those topographical and geographical conditions which must, to a large extent, control possible future development. Opinions here expressed relative to individual outcrops, as well as estimated thickness of bituminous sand and of overburden, are necessarily based in many instances on incomplete information. It is only after detailed exploration by means of adequate equipment, that the true value of any area can be finally determined.

Up to the present, only a limited amount of development work has been undertaken by private individuals or by companies. Meanwhile, it should be distinctly understood that the area of bituminous sand which is actually available for commercial development by methods recognized at the present time, is relatively limited—a statement that will be amply borne out by a study of the various maps and sections designed to illustrate this report.

In the study of possible petroleum fields, an appreciation of the probable genesis of petroleum is obviously of practical importance. There appears to be no valid reason, however, apart from its purely scientific interest, for discussing in the present report either the probable conditions that have resulted in the formation of the secondary deposits at McMurray or the origin of the bituminous content. Geologically the bituminous sands apparently represent the McMurray formation and directly, but unconformably, overlie limestones of Devonian age. Originally in the form of soft sandstones and uncompacted sands, subsequent and more or less complete impregnation by heavy asphaltic hydrocarbons has resulted in the present coherent material. Overlying the bituminous sands are various Cretaceous sediments and glacial drift.

As evidence regarding the geological horizon of the deposits, the writer, in 1914, submittted certain shells which he had discovered on Hangingstone river, to E. M. Kindle, Invertebrate Palæontologist of the Geological Survey of Canada. Subsequently, Dr. Kindle submitted the following report:—

The specimens of Gasteropod shells from the bituminous sands near McMurray which you transmitted to me for determination, appeared to represent undescribed species and were referred to Dr. T. W. Stanton, who writes regarding them as follows.

Apparently only two species are represented and they are both undescribed. The larger, smooth form is a Campeloma. The other species, represented by only three small individuals, probably all immature, is a Melanoid shell possibly belonging to the genus Pachymelania. The oldest record of Campeloma in America is in the Bear River formation of Wyoming which lies at the base of the Cretaceous. The genus Pachymelania was described from the same formation. It should not be inferred from this that the "tar sand" is to be correlated with the Bear River formation, but the occurrence of these two genera in the "tar sand" is not surprising since the formations have approximately the same position in the geological column.

It follows from the above that, although the evidence of these shells is not sufficiently clear to either confirm or oppose the early reference of these beds to the Dakota by McConnell, they do indicate an early Cretaceous age for them.

Tar Springs

For many years the occurrence of so-called "tar springs," or seepages of bitumen, has been recognized in the McMurray area, and these have constituted a limited source of supply for rivermen and others for patching boats and canoes and the roofs of cabins. Although familiar with upwards of 40 of these "springs," the writer does not know of any of which the diameter exceeds four feet. In themselves, therefore, they are of no commercial significance. Apparently, no one had investigated the immediate origin of the bitumen in these "springs," and uninformed people have frequently pointed to them as definite indications of the presence of petroleum pools. Two of the "springs" were, therefore, excavated in 1914 in order to determine the immediate origin of the more or less pure bitumen which they contain. In each instance the result was the same. Instead of coming from below, the bitumen merely seeps laterally from slightly inclined beds of particularly rich, coarse-grained bituminous sand. An underlying impervious clay parting, together with a small local depression, makes possible the formation of the small pool of bitumen.

An interesting type of occurrence, somewhat analogous to the "tar springs," was observed near the north boundary of sec. 24, tp. 95, range 11, east of Athabaska river. Irregular veins of pure bitumen up to 6 inches in thickness, though apparently of very limited extent, are found intruded upward into the sandy soil overlying the bituminous sand. Apparently none are of sufficient extent to be of economic importance.

Contacts

The lower limit of the bituminous sand where exposed, is well defined by its contact with the Devonian limestone (Plate V). There is not, however, any such well-defined upper limit. Nevertheless, there is, in many instances, a more or less well-defined line between what may be termed the high-grade material of commercial value, and what must be classed as low-grade material of little or no value. In the majority of well-exposed sections, the richer material occurs in the lower part, shading off into the leaner grades in passing upward. Only rarely in the southern part of the field is high-grade sand found immediately below the superimposed sandstones, shales and drift, although in some cases deterioration is obviously due to the leaching action of water. In the northern portion of the field, where severe erosion has removed overlying sediments and a part of the bituminous strata, high-grade material frequently comprises the entire exposed section.

Within certain areas of considerable extent the upper limit of underlying limestone is frequently fairly uniform in elevation. Within such areas—and apart from minor local erosion—the thickness of bituminous sand will also be fairly uniform. In certain instances, however, outcrops

are partly obscured by talus piles and drift, or may extend below water level. Variation in the percentage of bituminous content, grading of mineral aggregate, percentage of moisture, and of sulphur, etc., are also met with, often within comparatively narrow horizontal and vertical limits. In such cases drilling or excavation must supplement imperfect surface indications.

Variation in Character of Deposit

In estimating the probable economic importance of any of the sub-areas as represented by various outcrops, there are certain factors which require careful consideration. Of these, the following may be briefly referred to:—

Interstratified Partings

It is noticeable that the lower part of nearly all exposed sections consists of unstratified sands, which, prior to impregnation by the bitumen, were to a large extent apparently uncompacted. Consequently, the lower portion of the resulting bituminous sand is generally of a more or less homogeneous character. In places, however, homogeneous beds do show stratification frequently accompanied by pronounced false bedding; and, as a rule, the more marked such stratification becomes, the lower is the grade of bituminous sand. In passing upward, narrow bands of sandstones, clay-ironstones, clays, lignites and occasional quartzites, ranging in thickness from one-quarter inch to several inches, are found interbedded with the originally uncompacted sands. In places such non-bituminous strata gradually increase until they entirely replace the bituminous sand itself. Areas within which banding is pronounced, appear to form " islands ", and doubtless reflect local conditions—such as shallow water and action of modified currents—under which sedimentation took place. The continuity or persistence of any parting varies with its thickness. An interstratified band, 3 inches thick, may at times be traced for hundreds of feet, while the length of a band, one-quarter inch thick, rarely exceeds a few feet. Materials of which such partings are composed vary, but the more important may be briefly enumerated:—

1. Clay. This is usually tough, sticky, and impervious, showing little or no trace of bituminous impregnation. Thickness may range from that of a knife blade to 12 inches.
2. Sandy Clay. The proportion in which the sand and clay are combined is, of course, variable. When the sand predominates, the content in bitumen may be as high as 4 per cent. When the clay predominates, the percentage of bitumen is practically nil.
3. Lignite seams and roughly stratified partings of lignitic particles are frequent. At times these attain a thickness of several feet, as in sec. 33, tp. 94, range 11.
4. Roughly stratified partings of fine gravel, much of which would remain on a ½-inch sieve.
5. Narrow sandy partings having a high percentage of fine micaceous particles.

Exposure of bituminous sand under light overburden on south bank of McKay river.

PLATE XVI

Exposure of bituminous sand under light overburden, on east shore of Athabaska river (sec. 24, tp. 95, range 10).

PLATE XVII

Exposure of bituminous sand on north bank of Ells river (sec. 20, tp. 95, range 11). Although the overburden is practically nil, the section is highly banded and of doubtful commercial value.

It will probably be possible to incorporate in paving mixes, a very limited percentage of material from the thinner impure partings. To what extent this may be true can only be determined by experimental mixes.

During rainy weather, the banded structure can not be readily distinguished in the wet face, but immediately on drying, the interstratified bands stand out. Along the upper surfaces of the impervious bands, bitumen tends to collect, forming zones of greater enrichment. Consequently, such partings in beds of otherwise rich bituminous sands, can frequently be detected during warm weather, by horizontal lines of seepage. In considering the probable value of any deposit for paving purposes, the desirability of determining the extent to which interbedded impurities are present is obvious. A banded structure frequently persists throughout a complete vertical section, and it is unfortunate that homogeneous bituminous sand, when present, nearly always underlies this inferior material.

Thickness and Character of Overburden

Near Boiler rapids (township 87, range 14), 14 miles south of the latitude of McMurray, the overburden is not less than 400 feet thick, but on passing northward, it becomes a much less serious factor. (Plates XV, XVI, XVII.) This feature is illustrated by a series of East-West sections accompanying this report. It is reported that mounding work in connexion with subdivision surveys in township 97, uncovered bituminous sand at points quite two miles west of Athabaska river. It has not been determined whether the material is in place or is merely float.

Information regarding the actual character of overburden is based largely on certain incomplete vertical sections. Correlation of a number of these indicates, however, that the overburden is chiefly glacial till, sand, soft shales and occasional lenses of soft sandstones. To remove such material should not be difficult.

In view of the above considerations it will be seen that, in considering possible commercial development of bituminous sand areas, thickness and character of overburden and ground available for disposal thereof, freedom from impure partings, uniformity and degree of enrichment, and conditions affecting transportation, may be considered as among the principal controlling physical factors. Other factors, such as fuel supply, labour, etc., will not be discussed here.

Variation in Grading of Mineral Aggregate

A bituminous sand that will comply with standard paving specifications, should primarily possess uniformity in grading of mineral aggregate, and uniformity in percentage of a suitable associated bitumen. Within fairly well-defined limits, each of these constituents may be modified to conform with specified requirements. Indeed, apart from considerations of transportation, this selective feature has, in the past, had probably more to do in discouraging the development of many promising

deposits of bituminous sand in the United States, than any other single factor. In a body of siliceous sand of such wide areal extent as that of the McMurray area, variation in the grading and purity of the mineral aggregate must be expected, and does exist—even within comparatively narrow limits. In a number of cases, however, where the grading of the mineral aggregate is not satisfactory, a desired grading may be obtained by a combination of the bituminous sand from two, or even three, outcrops. Such a procedure has been successfully adapted by the City Street Improvement Company of San Francisco, Cal., and by the Kentucky Rock Asphalt Company of Louisville, Ky.

Variation in Bituminous Content

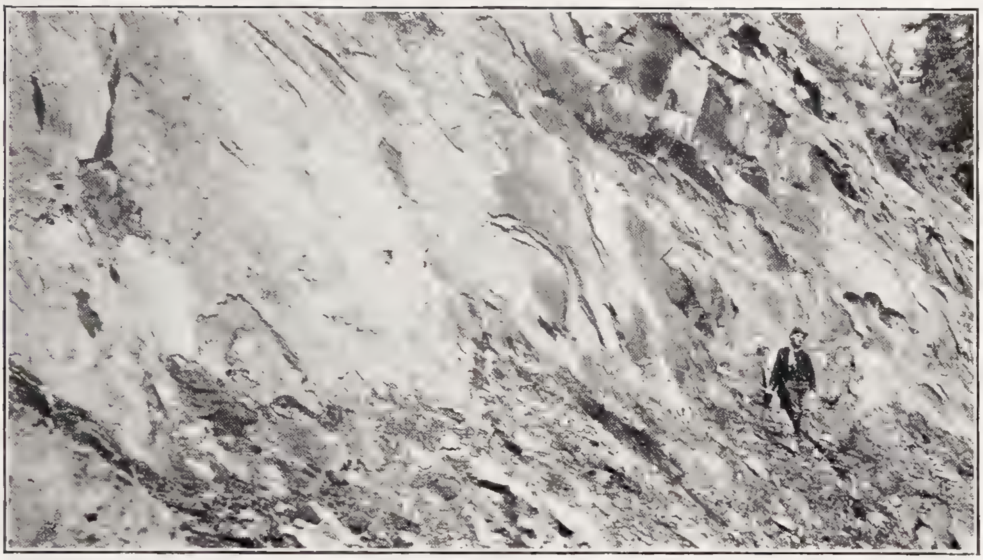
To some extent the degree of impregnation has depended on the grading of the sand. The medium-grained and moderately compact deposit is usually the richest, whereas the finer aggregates have apparently somewhat retarded complete saturation. At the time of impregnation of the sands, coarser aggregates would probably retain the greater part of the oil, while water would fill pore spaces or voids in the finer aggregates. Thus, previous to elevation and erosion, the finer grained sands would be water-bearing. Subsequent to erosion however, when water had been withdrawn from the finer grained sands, an appreciable quantity of oil would fill the voids vacated by evaporating water. Theoretically this type of saturated sand should show some mineral cement, and leave a somewhat resistant sandstone. Thus the percentage of associated bitumen varies widely in many exposed sections examined. In a large number of outcrops measured, however, a bed of bituminous sand of commercial dimensions, with a sufficiently uniform impregnation of bitumen, was found. It is probable that lack of uniformity in the percentage of bitumen present in any one particular bed selected, will be one of the least serious difficulties to be overcome.

Weathering of Bituminous Sand

Where overburden is light—as for example, in sec. 25, tp. 97, range 11—low-grade outcrops are characterized by a distinct type of erosion. (Plate XX). Along the upper edge of the bituminized strata, sharply defined, notch-like gullies, accompanied in some places by roughly vertical fissures (secs. 5, 8, and 17, tp. 90, range 9) occur at frequent intervals in the friable and loosely compacted material. When the lower strata of such exposures consist of high-grade material, the indentations do not extend downward into it. So typical is this form of weathering, that with experience, it is possible to recognize low-grade and worthless exposures by this indication alone. Talus piles may also be considered as a general indication of the character of adjacent exposures. Where such piles remain loose and uncompacted, the outcrops from which the material is derived are usually of low grade; where talus piles become cemented together to form a compact mass or beach, the adjacent outcrops are usually composed of rich material.

To some extent the percentage of associated bitumen, and the prevalence of impure partings, may be recognized in the weathering of an exposed section. Beds of high-grade, homogeneous bituminous sand are usually marked by a typical conchoidal cleavage roughly parallel to the

PLATE XVIII



Exposure on north bank of Steepbank river (sec. 30, tp. 92, range 9), illustrating typical massive structure and cleavage of richer bituminous sand.

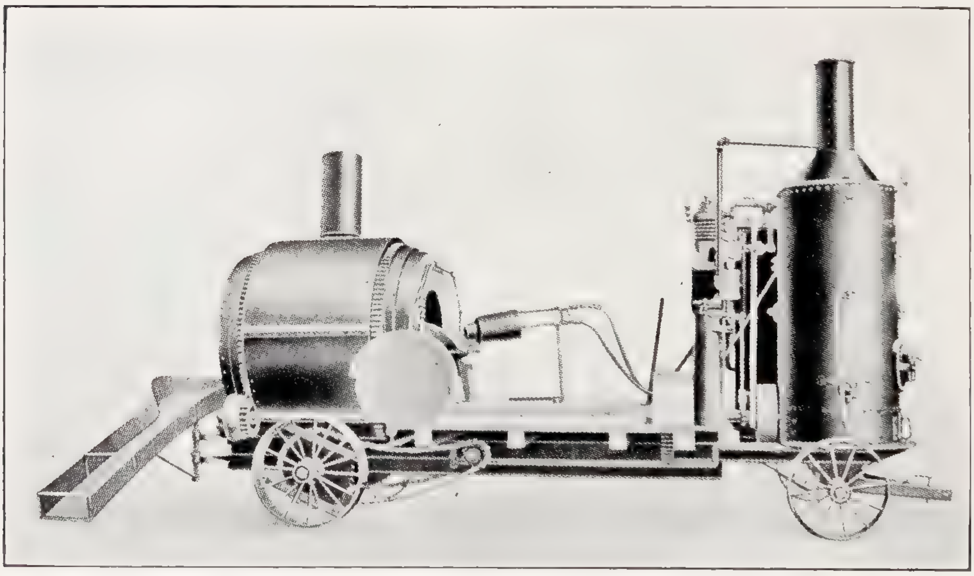
PLATE XIX

Exposure on east side Athabaska river (sec. 5, tp. 88, range 12) illustrating angular weathering of low-grade bituminous sand.

PLATE XX

Typical erosion of low-grade bituminous sand showing sharply defined, notch-like gullies, (sec. 25, tp. 97, range 11).

PLATE XXI



Rapid heated mixer used in connexion with demonstration paving, 1915.

face (Plates I and XVIII). Such a cleavage or flaking off is especially noticeable where heavy overburden has set up transverse pressure. As the percentage of contained bitumen becomes low, the cleavage becomes more and more angular. (Plate XIX.)

General Conclusion

At many points over a wide area, large tonnage of good bituminous sand can be found. In almost every instance certain conditions are favourable, while others are unfavourable. It is only by carefully estimating the relative advantages and disadvantages in each individual sub-area, that an intelligent selection may be made. From a topographical standpoint, it is evident that triangular areas situated at the junction of two streams, offer distinct advantages for removal and disposal of overburden. Moreover, sub-areas that are entirely favourable for commercial development on a comparatively small scale—as for example when bituminous sand is required as a surfacing material for roads[1]—might be of little value if distillation with recovery of crude petroleum on a large scale were contemplated.

It will probably be impossible for many years to estimate, with any degree of accuracy, the tonnage of bituminous sand commercially available in the McMurray area. If it is proposed to utilize the material for paving purposes a large portion of the deposit may be eliminated from consideration, owing to recognized variation in grading of sand aggregate. If, on the other hand, some form of separation or distillation is adopted, such a consideration should not seriously reduce the tonnage otherwise available.

Character of Bituminous Sand

BASED ON ANALYSES AND PHYSICAL DETERMINATION

In 1913 and 1914 a number of core samples of bituminous sand were secured from representative outcrops, at a number of points throughout the McMurray area. These samples were analysed[2] and the percentage and character of associated bitumen and grading of mineral aggregate determined[3]. In considering the following abridged results it should be remembered that the average depth from the face at which samples were taken did not exceed 4 feet, and that different results (see Table IV) may be obtained from samples taken at points removed from actual exposures. It is considered, however, that the analyses given, furnish a fair indication of the general character and degree of enrichment of a large tonnage of bituminous sand. Other analyses, not quoted, have shown a bitumen content in excess of 20 per cent, but pending further investigation these are considered as indicating local enrichment only.

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[1] During a period of 15 years, prior to 1916, the greater part of the bituminous sand mined in California was obtained from quarries operated by the City Street Improvement Company, near Godola, Cal. The strata of bituminous sand mined by this company have an aggregate thickness of approximately 65 feet, but up to and including the year 1916, the area actually affected by quarrying operations did not exceed 6 acres. On the basis of the quantity of asphalt cement entered for consumption in Canada during the fiscal year 1913-14, 10 acres of bituminous sand, 50 feet in thickness, would supply the paving requirements of the provinces of Manitoba, Saskatchewan, and Alberta for a period of approximately 24 years.

[2] Unless otherwise stated all analyses and determinations are by the writer.

[3] Hubbard, Prévost, and Reeve Charles F.; Methods for the Examination of Road Materials; U.S. Dept. of Agriculture, Bull. 314, 1915.

Richardson, Clifford; The Modern Asphalt Pavement, 2nd Ed., Chap. 24.

TABLE IV

Abridged Analyses of Samples of Bituminous Sand from the McMurray Area

Test No.	—	Passing mesh								Per cent contained bitumen
		200	100	80	50	40	30	20	10	
11	Athabaska river	2	11	54	16	10	5	2	....	14
12	"	6	54	25	13	....	....	....	....	15
12	"	7	77	14	2	....	....	....	....	16
15	"	24	64	9	3	....	....	....	....	17
15	"	3	38	19	40	....	....	....	....	9
16	"	9	33	11	47	....	....	....	....	12
21	"	3	5	1	8	7	15	33	27	15
21	"	4	26	11	48	3	2	3	3	20
22	"	11	70	14	5	....	....	....	....	12
47	Christina river	3	6	8	12	14	45	12	....	11
49	"	3	15	11	70	1	....	....	....	14
52	"	2	35	12	51	....	....	....	....	17
52	"	4	34	16	46	....	....	....	....	15
39	Clearwater river	4	14	14	48	9	7	4	....	14
43	Hangingstone river	3	22	9	51	9	4	2	....	15
31	Horse river	5	38	8	47	2	....	....	....	16
32	"	5	47	16	32	..	....	....	....	16
33	"	5	36	14	45	....	....	....	....	15
34	"	10	33	19	37	1	....	....	....	17
35	"	4	27	11	56	2	....	....	....	9
35	"	7	77	5	11	....	....	....	....	17
36	"	4	40	5	51	....	....	....	....	16
36	"	5	39	27	29	....	....	....	....	11
37	"	3	35	15	57	....	....	....	....	18
38	"	5	42	18	35	....	....	....	....	11
38	"	4	30	18	47	1	....	....	....	16
73	McKay river	2	49	26	22	....	....	....	....	16
74	"	6	25	16	40	4	9	....	....	18
64	Ells river	6	75	18	1	....	....	....	....	15
67	"	6	53	19	20	....	....	....	....	16
63	Muskeg river	7	10	1	27	20	16	10	6	9
54	Steepbank river	3	8	2	25	16	20	15	9	14
55	"	7	4	1	12	10	17	27	22	16
56	"	2	4	1	42	22	13	9	4	17
58	"	5	33	2	43	7	4	2	3	16
59	"	3	14	2	72	5	5	1	....	16
61	"	7	10	1	27	20	16	10	6	8

The physical characteristics of a representative sample of the bituminous sand, and of the bitumen itself[1] may be briefly summarized thus:

	Per cent
Crude bituminous sand—	
Specific gravity 25° C/25° C	1·75
Moisture	1·3
Bitumen soluble in CS_2	18·5
Sand	80·2

Characteristics of Sand

The sand consists, for the most part, of clear quartz grains. In form the grains are most irregular, varying from sharply angular to oval, water-worn shapes. Judging from the grading of the sand, the bulk of which ranges from 40 to 80 mesh, the greater part may be considered as originating as shore deposits.

[1] For further reference to the character of separated bitumen, see also "A Chemical Investigation of the Asphalt in the Sands of Northern Alberta," by Wm. F. Seyer. Jour. Am. Chem. Soc., June, 1921.

The following is an analysis of sand combined from samples taken from six representative outcrops:—

	Per cent
SiO_2	95·50
Al_2O_3	2·25
CaO	0·50
Fe_2O_3	0·35
MgO	0·23
Less loss on ignition	1·50
	100.33

Characteristics of Separated Bitumen*

Specific gravity, 25°C/25°C	1·018
	Per cent
Fixed carbon	7·23
Sulphur	4·85
Bitumen soluble in 76° naphtha	82·8
Bitumen soluble in 88° naphtha	78·2
Carbenes	trace
Ash**	trace
Saturated compounds in 88° naphtha solution	39·6
Unsaturated compounds in 88° naphtha solution	60·4
Penetration at 115° F	too soft
Penetration at 77° F—	
(100 grms. 5 sec.)	too soft
(100 grms. 1 sec.)	9·0 mm.
Penetration at 32° F—	
(100 grms. 5 sec.)	2·5 mm.
Ductility at 77° F	100 cm.+
	Per cent
Volatile 160°C.—5 hours (Using New York testing oven)	11·2
Volatile 205°C.—5 hours (Using New York testing oven)	14·2
Volatile 250°C.—4 hours (Using New York testing oven)	18·8

*All extractions by use of CS_2.
**Fine mineral matter not removed by extraction.

Characteristics of Residual Bitumen After Heating.

—	160° C. 5 hours	205° C. 5 hours	250° C. 4 hours
Specific gravity, 25° C/25°C	1·021	1·025	1·028
Fixed carbon	8·99%	10·77	12·33%
Sulphur	none	none	none
Carbenes	trace.	trace.	trace.
Fusing temperature	106° F.	114° F.	125° F.
Penetration at 115°F	too soft	too soft	too soft
Penetration at 77° F.—			
(100 grms. 5 sec.)	26·2 mm.	12·2 mm.	5·8 mm.
Penetration at 32° F.—.			
(200 grms. 1 minute)	10·5 mm.	5·3 mm.	2·4 mm.
Ductility at 115° F	100 cm.+	100 cm.+	34·5 cm.
Ductility at 77° F	100 cm.+	99 cm.+	45·0 cm.
Tensile strength at 155° F			0·3 kg.
Tensile strength at 77° F			1·5 kg.
Tensile strength at 32° F			25·5 kg.

In 1913 the writer forwarded to Mr. Herbert Abraham a sample of Alberta bituminous sand. In Mr. Abraham's book ("Asphalt and Allied Substances"), published in 1918, appears the following report on the separated bitumen.

(Test 7)	Specific gravity at 77° F	1·022
(Test 9b)	Penetration at 77°F	too soft for test
(Test 9c)	Consistometer hardness at 115° F	0·0
	Consistometer hardness at 77° F	0·0
	Consistometer hardness at 32° F	2·7
(Test 10b)	Ductility at 115°F	2·0
	Ductility at 77°F	7·0
	Ductility at 32°F	12·5
(Test 15a)	Fusing point (K. and S. method)	50°F.
(Test 16)	Volatile at 500° F. in 4 hours	17·9 %
(Test 19)	Fixed carbon	10·55%
(Test 21a)	Soluble in carbon disulphide	97·3 %
(Test 21c)	Free mineral matter	2·7 %

The non-volatile matter tested as follows—

(Test 7)	Specific gravity at 77°F	1·028
(Test 9b)	Penetration at 77°F	52·0
(Test 9c)	Consistency at 115°F	3·7
	Consistency at 77°F	8·5
	Consistency at 32°F	49·3
(Test 9d)	Susceptibility factor	36·5
(Test 10b)	Ductility at 115°F	34·5
	Ductility at 77°F	45·0
	Ductility at 32°F	0·5
(Test 11)	Tensile strength at 115°F	0·3
	Tensile strength at 77°F	1·5
	Tensile strength at 32°F	25·5
(Test 15a)	Fusing temperature (K. and S. method)	125°F.
(Test 19)	Fixed carbon	12·33 %

For purposes of comparison the following abridged data concerning certain well known natural asphalts are given—

1. Trinidad asphalt-cement—

Dow penetration at 77°F. (100 grms. 5 secs.)	50
Fusing temperature	113°F.
Susceptibility factor	45·2
Ductility at 115°F	15·0
" 77°F	21·5
" 32°F	1·0
Tensile strength at 115°F	0·25 kg
" " 77°F	0·75 "
" " 32°F	15·0 "

2. Bermudez asphalt-cement—

Dow penetration at 77°F. (100 grms. for 5 secs.)	50
Fusing temperature	113°F
Susceptibility factor	53
Ductility at 115°F	17·5 cm.
" 77°F	17·0 "
" 32°F	0·0 "
Tensile strength at 115°F	0·50 kg
" " 77°F	1·10 "
" " 32°F	14·0 "

In January, 1924, a sample of bitumen separated from Alberta bituminous sand was submitted to Dr. J. H. Young, Senior Industrial Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa. The following preliminary report has been received:—

This specimen of bitumen was blown at a temperature of 450° F., with the following results:—

Hrs. blown	M.P. °F. (cube method)	Penetrations (100 grms. for 5 secs.) at 77° F.	Penetrations (100 grms. for 5 secs.) at 122° F.
3½	—	29[c]	Soft[a]
6½	—	12½	100
10½	240	4	18[b]

[a] Soft, but very tacky.
[b] Harder than Mexican product of same M.P. but tougher.
[c] Needle came out clean.

Dr. Young's findings indicate that the bitumen can be industrially blown to a consistency that is commercially useful. He did not however ascertain the blowing loss. To learn this loss it would be necessary to have a one-gallon sample or about ten pounds of the bitumen.

CHARACTER OF BITUMINOUS SAND BASED ON RESULTS OF SHAFTING

In 1913, the writer pointed out the undoubted necessity of detailed prospecting by means of adequate equipment, in order to definitely ascertain the true character of bituminous sand strata at points removed from actual outcrops. Each subsequent year has adduced additional evidence in substantiation of the above. Until quite recently, however, knowledge of the character of the bituminous sand itself, has necessarily been based entirely on information regarding material secured by core-drilling of actual outcrops by means of standard asphalt augers. Surface sampling by means of shallow trenches has been avoided, since it is quite obvious that such sampling can only prove misleading.

During the summer of 1924, it was found possible to undertake a very limited amount of shafting in connexion with other work. One test pit, 12 feet deep, was sunk at a point 170 feet from the west shore of Athabaska river, in sec. 35, tp. 95, range 11, and two shallow shafts, No. 1 and No. 2, 42 and 30 feet deep respectively, were sunk in sec. 14, tp. 89, range 9, at points approximately 150 feet from the east shore of Clearwater river. Ground elevation at the top of No. 1 shaft was 854 feet, and at the top of No. 2 shaft, 836 feet. Water level of Clearwater river was 792 feet.[1] Both shafts were commenced on a bench or terrace, and immediately at the foot of the steep rise of the main valley wall. General descending sections of the above shafts are as follows:—

Shaft No. 1

Elevation
854–839.....Overburden (chiefly clay).
839–826.....Bituminous sand.
6-inch ledge of clay ironstone.
826–817.....Clay.
817–812.....Clean sand.
812–808.....Clean sand.
(core sample)

Shaft No. 2

Elevation
836–820.....Overburden (clay and sandy gravel).
820–806.....Bituminous sand.
806–801.....Bituminous sand.
(core sample)

From the above it will be seen that, although the two shafts are less than 700 feet apart, it is impossible to correlate the individual strata passed through.

[1] All elevations are referred to sea-level datum.

In sinking the above shafts, an opportunity was afforded to observe certain conditions affecting bituminous sand at points somewhat removed from actual outcrops. It is fully realized, however, that final conclusions regarding the true character of bituminous sand, when unaffected by any alteration and movement, can only be arrived at by shafting or drilling at points much farther removed from exposures.

As regards the character of the bituminous sand passed through and conditions encountered, certain features may be briefly noted:—

(a) Movement due to Pressure. Within and adjacent to stream valleys, the bituminous sand has been affected in marked degree by the pressure of overburden. Such pressure has caused slipping, varying in intensity with topographical conditions and with weight of overburden. In places the bituminous sand has become laminated to such an extent as almost to resemble a thinly bedded shale. Frequently the laminae have a slickensided appearance, due in part to the deposition, by water, of minute flakes of mica along slip planes. In general, such planes appear to lie roughly parallel with the general ground slope of the valley, flattening out to lower angles as the lower slopes are reached. Cross-checking, frequently but not always normal to slip planes, is also notably developed. Material affected in this manner has a markedly musty odour.

It appears that slipping has affected the beds of bituminous sand, (although with decreasing intensity), well back into the main valley slope. Where pressure has decreased, owing to a receding valley wall or other cause, richer bituminous sand has become resealed into a fairly homogeneous mass, although it still breaks along the original slip planes. On the other hand, in the leaner bituminous sand, slip planes usually remain partly or altogether open.

It will thus be seen that the site for a final test shaft should be selected at some point where pressure has not caused slipping in the bituminous sand. This does not necessarily imply shafting through heavy overburden, since, in passing northward, the Athabaska valley broadens out towards the east into what was at one time an extensive flood plain or estuary.

(b) Sulphur. Sulphur occurs either in the form of white sulphur compounds deposited along slip planes, and probably derived from impregnated swamp water, or as nodules of iron pyrite. Obviously, where sulphur is deposited in the bituminous sand by circulating waters, the amount present will vary according to the extent of slipping that has taken place. Thus, holes drilled for blasting in highly fissured material, became rapidly filled with black sulphur-bearing water. Holes drilled in slightly fissured material, filled with water very slowly and showed only a trace of sulphur. Consequently, low-sulphur areas will probably be those in which, owing to topographical conditions, movement within the bituminous sand has been at a minimum. The extent to which sulphur is present also appears to vary with the grading of the sand. Thus, in certain pockets of loosely compacted, coarse sand, the odour of hydrogen sulphide was very marked; in finer grained, compact material the odour was scarcely noticeable or absent altogether. High sulphur sands are usually marked by a somewhat lighter colour. It may be noted that a composite

core sample of bituminous sand from pit No. 2 showed a sulphur content of 4·3 per cent, while a composite core sample from the N.E. $\frac{1}{4}$ sec. 8, tp. 89, range 9, showed a sulphur content of 7·4 per cent. In neither instance was the character of the sulphur determined.

Occasional nodules of iron pyrite are found throughout the bituminous sand. In the pits referred to above, however, they are chiefly segregated in thin beds or lenses up to 15 inches in thickness. With the nodules of pyrite, are usually associated other nodules of slightly calcareous and slightly pyritiferous, clay ironstone (siderite), and large and small fragments of wood. Certain of these wood fragments (which apparently were originally accumulated as drift wood), have been partly or wholly carbonized, whereas others, that have been completely insulated by rich bituminous sand, are well preserved and appear to have undergone but little alteration.[1] Possibly such preservation may be considered as an indication that impregnation of the sands by bitumen followed very shortly after or even during their deposition.

(*c*) *Interstratified Partings.* Where bituminous sand occurs at a contact with recent sediments (as glacial till), leaching-out and hardening due to oxidation, have taken place. Where partings of bituminous sand occur within the earlier Cretaceous clays, the material is fresh and unaltered. This may indicate that impregnation by hydrocarbons occurred after deposition of strata associated with the bituminous sand was complete. Occasional thin strata of jointed clay ironstone up to 6 inches in thickness also occur, and have acted as sills above which bitumen has collected. After passing through such strata, ropes of bitumen, several feet in length, were observed hanging near the walls of the shaft. At times immediately below the clay ironstone water circulates freely.

(*d*) *Filaments of Bitumen.* On pulling apart fragments of fresh bituminous sand of the richer grades fine filaments or threads of bitumen are usually observed. The occurrence of these threads is more pronounced when the sand is broken along lines normal to the slip planes than when broken along lines parallel with such planes. Their number and length are also affected by the percentage of moisture present and by the grading of the sand aggregate, being of greatest length when associated with the coarser sand. When bituminous sand possesses a uniform grading of aggregate, its degree of enrichment may be roughly determined by the character and number of the filaments of bitumen. When cut by a spade or similar digging-tool, the snapping of the threads is often audible at a distance of 3 to 4 feet.

(*e*) *Local Enrichment near Outcrops.* From a comparison of samples secured by shafting, and by boring at a depth of approximately 3 feet inside nearby outcrops, it appears that, to some extent, a local zone of enrichment has been formed adjacent to exposures. This is probably due to gradual gravitation of bitumen toward an oxidized and partly sealed face. The depth to which alteration has extended, will be governed to some extent by angle of slope of outcrop. Thus, on steeply inclined exposures, flaking off of bituminous sand at comparatively fre-

[1] Merriam, John C. Bulletins issued by University of California on investigations at Rancho La Brea, Cal.

quent intervals removes the more weathered surface and doubtless decreases somewhat the depth to which alteration is effective. On the other hand, where low-lying deposits, less steeply inclined, are exposed to weathering agencies, the zone of alteration may extend to greater depth. In this connexion results obtained on distilling bituminous sand in the Whitaker-Pritchard retort in October, 1924, are of interest. Bituminous sand which had been subjected to exposure and oxidation gave an appreciable amount of semi-liquid bitumen, whereas the amount of bitumen derived from fresh bituminous sand, under similar conditions and temperatures, appeared to be practically nil.

(*f*) *Instability of Fresh Bituminous Sand.* The writer has always maintained that excavation of bituminous sand by underground mining methods, is not commercially feasible. Experience in the shafts under consideration substantiates this view. Shafts Nos. 1 and 2 were each 11 feet long by 5 feet wide. They were timbered at frequent intervals by birch square-sets, lagged with 2-inch plank. Corners were reinforced by continuous strips of 2- by 4-inch and 2- by 6-inch scantling. Cross braces of round birch served as intermediate supports. Contacts between clay and bituminous sand constitute lines of weakness and water-seeps were common. Particular care was, therefore, observed at such points.

The above method of timbering proved satisfactory as a temporary measure, but at the end of four weeks the shafts were no longer safe. This was chiefly due to constant movement in the body of bituminous sand, more especially where water-seeps increased the tendency to caving, and to the fact that there is no solid rock strata to which the timbering can be secured. Props, even when set on a broad base of heavy plank, rapidly settle.

(*g*) *Weathering of Fresh Bituminous Sand.* In unaltered bituminous sand the bond between the bitumen and grains of sand is weaker than in the case of weathered material. Consequently, surfaces that have been sheared by spades or other cutting-tools, are of a distinctly grey to greyish-white shade. Indeed, bitumen may be readily brushed by the hand from a fresh wall of a shaft, thus exposing the white grains of silicia. A similar condition is even more marked in the case of fresh auger cuttings derived by boring unaltered bituminous sand. In a very short time, however, sufficient bitumen exudes from the mass to re-coat the particles with a dark brown film. On exposure to the atmosphere for a short time, the sand becomes harder and almost black in colour, moreover, on breaking fragments apart after exposure the prevalence of filaments of bitumen is notably less.

Prior to 1924, all excavation by the writer had been made at outcrops along the banks of streams where weathering had affected the character of the bituminous sand. Under such conditions it was found necessary either to use heated spades and shovels, or to clean such tools by scraping at frequent intervals. In excavating unaltered bituminous sand however, it was rarely necessary to clean the cutting-tools. This may be attributed to higher moisture content of the bituminous sand, and possibly to the lighter character of associated bitumen. In blasting weathered outcrops,

large lumps are broken out by the explosive. When blasting fresh material, bituminous sand usually disintegrates into smaller fragments. This may be due to higher moisture content.

Unaltered bituminous sand burns more freely than material from weathered outcrops. After ignition on a small wood fire, and if agitated to allow access of sufficient air for complete combustion, a long, yellow, and almost smokeless flame is given off. Surfaces exposed to the flame intumesce freely, giving off thick, sandy drops or semi-liquid flakes. The ash consists of a clean, greyish-white sand. Absence of agitation, resulting in incomplete combustion, gives a dense, yellowish-brown smoke of pungent odour.

In general the hardness of individual strata varies with percentage of moisture, grading of sand aggregate and degree of impregnation. Where banding is absent, there is rarely any distinct line between higher and lower grades of material, but rather a gradual merging of one into the other.

(h) Gas Sands. The odour of natural gas was noticeable at various elevations in shaft No. 2. At one point, sufficient gas was given off from a lenticular parting of unimpregnated sand, 10 to 18 inches in thickness, to burn freely for several minutes. Associated with this sand were numerous fragments of partly carbonized wood.

(i) Seepage of Hydrocarbons. As noted above, sites of shafts sunk during 1924 were within a short distance of an extensive outcrop, and at points where marked movement, subsequent infiltration of water, and possibly even partial re-deposition, had to some extent altered the bituminous sand. Consequently, these excavations did not furnish definite evidence regarding the extent to which seepage of hydrocarbons might be expected under more favourable conditions.

In passing through bituminous sand strata, walls of shafts and pools of standing water became covered with a thin film of dark brown bitumen after a lapse of four to six hours. At only one point (in shaft No. 1), 18 feet below the surface (elevation 834), a small seepage of dark green petroleum was observed. In no instance were seepages of sufficient quantity to permit of even small samples being secured.

In this connexion it is of interest to compare certain physical characteristics[1] of Alberta bituminous sand with those of bituminous sand from Pechelbronn, Alsace[2]; also of semi-solid and liquid hydrocarbons derived therefrom. In columns A, B, C, and D of the following table, are given results of,—

"A" Examination of Pechelbronn bituminous sand, and of bitumen or oil extracted therefrom.

"B" Examination of oil derived by natural seepage from Pechelbronn bituminous sand.

"C" Examination of Alberta bituminous sand secured from weathered outcrop, and of bitumen or oil extracted therefrom.

"D" Examination of unaltered Alberta bituminous sand secured by shafting and of bitumen or oil extracted therefrom.

[1] Determinations by Fuel Testing Laboratories, Mines Branch.

[2] Camsell, Charles, and Buisson, A.: "Recovery of Petroleum by Shafts and Galleries at Pechelbronn, Alsace, and at Wietze, Hanover, Germany." Memorandum Series No. 10, Mines Branch, Ottawa.

TABLE V

Physical Characteristics of Bitumens from Pechelbronn and McMurray

—	A	B	C	D
	per cent		per cent	per cent
Bitumen content of bituminous sand by CS_2 extraction....................	10·4	....	11·5	13·5
Apparent gravity of bituminous sand...............	1·38	....	1·4	1·9
Porosity of bituminous sand	45·5	....	30	22
Specific heat of bituminous sand....................	0·26	....	0·24	0·24
Specific heat of sand after extraction...............	0·22	....	0·20	
Sp. Gr. at 60°F. of bitumen or oil....................	0·914	0·885	1·050	1·020
Distillation range of bitumen or oil—				
5 per cent volume......	229°C.	128°C.	293°C.	288°C.
10 " "	246	167	310	305
20 " "	283	213	333	322
30 " "	322	270	346	325
40 " "	352	319	350	340
50 " "	370	351	361	342
55 " "	....	....	363	356
60 " "	378	364	....	358
65 " "	....	....	....	360
69 " "	380	....	....	....
70 " "	....	368	....	....
82 " "	....	370	....	....
Indication of cracking at	380	370	363	360
Sp. Gr. at 60°F. of distillate	....	....	0·934	0·911
Soluble in conc. H_2SO_4....	....	....	30%	37%

	A Temp.	A Time of efflux	B Temp.	B Time of efflux	C Temp.	C Time of efflux	D Temp.	D Time of efflux
		min.sec.		min.sec.		min.sec.		min.sec.
Viscosity of extracted bitumen or oil (Redwood Viscosimeter)..............	77°F.	4 20	44°F	8 17	....	....	....	....
	103	1 59	62	3 24	....	....	....	....
	126	1 28	74	2 35	....	....	....	....
	152	1 7	111	1 14	....	....	....	....
	166	1 2	139	0 56	....	....	....	....
	187	0 55	149	0 54	....	....	....	....
	213	0 47	163	0 50	....	....	....	....
	....	....	197	0 43	....	....	....	....
	....	....	....	....	205°F	44 20	206°F	10 59
	....	....	....	....	....	....	213	7 56

The comparison of relative porosity of the crude sands, and of specific gravity and viscosity of separated hydrocarbons, largely explains the absence of seepage in the shafts referred to above.

(j) Analyses. In sinking shafts Nos. 1 and 2, core samples were secured by the use of asphalt augers. The following analyses[1] of certain of these samples illustrate variation in bitumen content, percentage of moisture, and grading of aggregate:—

Test Number	Shaft Number	Elevation	Passing Mesh								Retained on 10	Moisture	Bitumen (1)	Bitumen (2)
			200	100	80	50	40	30	20	10				
1	1	828	2	46	4	42	2	2	1	1	1	6·0	18·0	19·1
2	1	827	1	31	3	64	2	1	1	1	......	3·4	19·2	19·8
3	1	826	2	35	4	59	......	......	......	......	......	6·0	19·0	20·2
4	1	825	1	24	4	62	7	1	0	1	......	6·8	25·2	27·0
5	1	824	2	15	2	37	11	12	12	5	4	8·8	16·1	17·7
6	2	817	1	18	2	54	12	7	5	1	......	2·0	10·6	10·8
7	2	816	1	31	3	58	3	2	2	......	......	1·0	12·1	12·2
8	2	815	1	16	3	46	11	8	10	5	......	2·8	10·2	10·5
9	2	814	......	16	3	60	13	5	2	1	......	2·4	10·3	10·6
10	2	813	1	20	3	60	7	4	4	1	......	2·6	12·1	12·5
11	2	812	2	20	3	60	7	4	3	1	......	2·8	13·1	13·6
12	2	811	2	19	3	58	7	5	5	1	......	2·2	13·6	13·9
13	2	810	2	16	2	56	8	5	7	4	......	1·6	13·7	14·0
14	2	808	2	19	2	48	7	5	9	7	1	1·0	13·3	13·4
15	2	805	2	38	2	45	4	4	4	1	......	1·2	16·9	17·1

[1] Percentage of bitumen associated with bituminous sand as mined.
[2] Percentage of bitumen associated with dehydrated bituminous sand.

II. SURVEYS

Prior to the commencement of the writer's investigation in 1913, not even track surveys of streams tributary to Athabaska river were available. Subdivision and base line surveys did not extend north of the 23rd base line.

Topographical Maps

Topographical maps of certain areas adjacent to Athabaska river and tributary streams have been prepared, and comprise an aggregate of approximately 1,260 square miles lying between the 4th and 5th meridians[1]. These areas include:—

Tp. 87, R. 6 (N.W. ¼ of Tp.)
Tp. 87, R. 7 (N. ½ of Tp.)
Tp. 88 (W. ½, R. 6, and Rs. 7, 8, 9, and 10)
Tp. 89 (S. ¾ W. ½ R. 6; S. ¾ Rs. 7 and 8, Rs. 9 and 10.)
Tp. 90, 91, and 92 (Rs. 9 and 10)
Tp. 93 (Rs. 9, 10, and E. ½ R. 11)
Tp. 94, 95, 96, and 97 (Rs. 10 and 11)
Tp. 98 (Rs. 9, 10, and 11)
Tp. 99 and 100 (Rs. 8, 9, and 10)

A small portion of the above area was surveyed in 1915,[2] elevations at that time being based on the Alberta and Great Waterways Railway datum. Subsequently, on the completion of a line of precise levels from

[1] Unless otherwise stated, all land subdivisions referred to in this report, are west of the 4th meridian.
[2] Mines Branch maps Nos. 390, 391, 392, 393, 394, and 395, (1915), S. C. Ells.

Edmonton to Waterways, by the Topographical Surveys Branch of the Department of the Interior, it was found that a slight error existed in the railway datum, and an attempt has been made to alter accordingly the contours indicated on the original maps. However, the greater part of the area was mapped in 1922 and 1923, and the levelling was based on the revised datum.

Apart from level tie-lines, all elevations were established by means of transit and stadia measurements. Positions were also fixed by transit-stadia traverse lines, controlled by frequent ties with base line and sub-division monuments. In all, upwards of 2,800 miles of transit traverse were run, and the elevations of approximately 27,000 points were established.

Manuscript maps were drawn on a scale of one inch equals one thousand feet, and contours of twenty-foot interval have been indicated.[1] All major outcrops of bituminous sand are drawn to scale, although in indicating the limits of such exposures, the personal equation must be taken into consideration. Thus, in certain instances, outcrops obscured to some extent by slide or by patches of forest growth, are shown as one continuous exposure. In other instances, where such interruption has been more marked, outcrops, although obviously portions of one continuous bed, are indicated as a series of relatively small exposures. Of the many minor exposures observed, only a sufficient number have been indicated to illustrate the continuity of the deposit throughout the greater portion of the area surveyed. It may be noted that a considerable portion of the area was surveyed during winter months, and that certain minor outcrops and summer trails, may thus have escaped observation.

In a wooded country, unless traverses are run at very close intervals, it is inevitable that certain minor topographical features must be overlooked. Moreover, with the contour interval adopted, many local summits and minor detail of form cannot be shown. Thus, for example, township 97 (ranges 10 and 11) is essentially a sandy terrain, and is marked by many erosion pockets and gullies, possibly of aeolian origin. To indicate these would, in many instances, require a contour interval not greater than 5 feet. An attempt has, therefore, been made to generalize in the matter of contours. On the other hand, apart from valleys of principal streams, the surface of the country presents few abrupt topographical changes, and earth forms, such as ridges, mounds, and slopes, are usually smoothly rounded with easy gradients. So much so is this the case, that intermediate contours may be safely interpolated throughout a large portion of the area. Terraces due to differential denudation are a common feature along slopes of the larger valleys, but in general these are too narrow to be delimited by means of the contour interval adopted. It has also been difficult, at times, to determine the degree of detail justifiable in mapping certain sub-areas remote from Athabaska valley, and which are obviously of no economic interest. In certain respects, therefore, the maps might properly be considered as reconnaissance maps. On the other hand, they are sufficiently complete to illustrate correctly

[1] Although these maps are being published on a scale of one inch equals forty chains, blue-prints from the original large-scale tracings may be obtained on payment of cost of printing.

the general topography, and to indicate those areas where commercial development may be undertaken under most favourable topographical conditions. Obviously, "hogsbacks" offer topographical advantages from the viewpoint of removal of overburden and of subsequent quarrying operations. Along the ancient Athabaska valley itself, well-defined hogsbacks of commercial significance (as for example in secs. 30 and 31, tp. 92, range 9), are confined almost wholly to triangular areas lying at junctions with the larger tributary streams. Along the "younger" valleys of certain tributary streams, however, excellent examples of important hogsbacks are frequently met with, as for example, in secs. 7 and 8, tp. 94, range 11.

Positions of sand bars in Athabaska and Clearwater rivers, were determined between October 20 and 24, in 1923 and in 1924, at approximately extreme low water. Although it is fully realized that the position and outline of such bars are subject to change from year to year, it is felt that changes over a period of years are not so marked as is generally supposed. The position of the steamboat channel is also subject to corresponding local changes, notably in townships 98, 99, and 100. The channel indicated on the maps is that followed by river steamers in October, 1924.

In certain instances, owing to more or less constant change, it has been difficult to differentiate between sand bars and willow islands, and between willow islands and true islands. Thus, a sand bar which first appeared in the Athabaska river, in 1913 (sec. 8, tp. 90, range 9) is now a willow island, whereas a small island in the Athabaska river (sec. 2, tp. 96, range 11) has completely disappeared since 1920. Ice action and a fairly strong current, acting on easily eroded alluvial material, are responsible for the above condition. Distinctions between bars, willow islands and true islands must, therefore, be regarded as somewhat arbitrary.

In connexion with the above surveys, exposed thickness and extent of practically all outcrops of bituminous sand throughout the area have been determined. For reasons noted elsewhere, these measurements are omitted from the present report.

At many points lying from one to three miles east and west of Athabaska river, notably in townships 97, 98, 99, and 100, large and small fragments of bituminous sand float are found, either in mounding pits or adhering to the roots of large trees which have been blown over. These fragments do not possess characteristics of transported float, and apparently have originated from nearby sources.

Apart from McMurray settlement no roads have been constructed within the mapped area, but trappers' trails are fairly numerous. Although none have been surveyed, the approximate position of certain of these trails has been indicated on the topographical map. It should, however, be remembered that, with notable exceptions—as in the case of Horse River and Moose Lake trails—maintenance is of a very casual character, and trails may rapidly become obliterated by undergrowth and windfall. It is, therefore, suggested that too much dependence should not be placed on indicated trails. During the winter months the greater part of the area adjacent to the Athabaska valley, is served by toboggan trails leading to the various trapping grounds.

In connexion with work involved in the investigation referred to in this report, the writer has depended chiefly on man packing in summer and on toboggan transportation,—both with and without dogs,—in winter. In summer the use of pack horses has also been attempted but, owing to extensive muskegs and sloughs, (as indicated in Table I), and the general absence of trails, the greater portion of the area is unsuited to this method of transport. In certain portions of the area mapped east of Athabaska river, notably in townships 96-100 (inclusive), much of the soil is dry and sandy, and transportation by pack horses should prove effective.

Tables of Elevations

For convenient reference, the following abridged tables of elevations have been compiled, and unless otherwise indicated[1] are based on surveys by the writer. Although it has not been possible in every instance to check elevations[2], it is believed that their accuracy is within the permissible error for transit-stadia determinations. Elevations of subdivison monuments refer to ground level (usually at base of iron post).

In the tables, elevations are referred to the northeast corners of sections, while quarter mounds are those on the north and east boundaries of the sections within which they are given. Thus N.E. 1 refers to the northeast corner of section 1; W. $\frac{1}{4}$ 1 and N. $\frac{1}{4}$ 1 refer to the quarter mounds on west and north boundaries respectively of section 1. The original survey of the 23rd base line was made in 1911. Later this line was partly re-surveyed, and a new line cut approximately four chains north of the original survey. Elevations given in the tables are referred to monuments on the original or more southerly of the two lines.

[1] Elevations determined by Topographical Surveys Branch, Department of the Interior, indicated (*).
[2] Elevations which have not been checked indicated (†).

TABLE VI

Tables of Elevations in the McMurray Area

Sec.	Township 87			Township 88						Township 89					Township 90	
	Range 6	Range 7	Range 8	Range 6	Range 7	Range 8	Range 9	Range 10	Range 11	Range 7	Range 8	Range 9	Range 10	Range 11	Range 9	Range 10
1					1,341*		1,248			1,484	1,368	1,203				1,106
N¼					1,344*					1,499*						
E¼							1,259			1,434		811	1,196			1,108
2					1,339*			1,286		1,477*		799				
N¼					1,332*					1,436*						
E¼					1,339*											
3					1,326*		1,245			1,437*						
N¼					1,319*					1,429*						
E¼						1,273										
4				1,389*	1,312*		1,260			1,437*					1,170	
N¼					1,301*					1,424*						
E¼				1,375*	1,321										1,161	
5						1,258	1,258	1,310		1,421*					1,074	
N¼										1,396*						
E¼						1,268	1,256									
6							1,284			1,255*		1,163				
N¼										1,305*						
E¼											1,345					
7					1,293	1,244	1,257	1,335†		1,382	1,248	901	1,303			
N¼					1,273			1,320†			1,223					
E¼							1,278	1,309†		1,387		1,160				
8					1,294	1,249	1,262			1,397	1,278	882	1,256†		1,152	
N¼					1,293	1,248		1,304		1,393	1,261	999				
E¼						1,249	1,263	1,300								
9				1,418*	1,312	1,267	1,239	1,289		1,416	1,303				1,171	
N¼					1,303		1,243	1,239		1,405	1,284				1,170	
E¼				1,404*			1,248								1,176	
10					1,324	1,276	1,226	1,296			1,334		1,204		1,192	
N¼					1,317	1,271		1,282			1,331				1,179	
E¼							1,236									
11					1,244*	1,284	1,221	1,288		1,487*	1,358	1,165	1,172		1,227	
N¼					1,329	1,281		1,281				1,074	1,184		1,196	
E¼					1,321*					1,478*		966	997			

TABLE VI

Tables of Elevations in the McMurray Area—*Con.*

Sec.	Township 87			Township 88						Township 89					Township 90	
	Range 6	Range 7	Range 8	Range 6	Range 7	Range 8	Range 9	Range 10	Range 11	Range 7	Range 8	Range 9	Range 10	Range 11	Range 9	Range 10
12						1,290	1,228	1,263	1,323*		1,382	1,203		1,351	1,319	1,104†
N½						1,287		1,270			1,372	1,194			1,254	
E½							1,232				1,374					1,071
13		1,414	1,433		1,329†	1,251	1,200	1,242	1,324†	1,538†	1,384	1,206			1,333	1,062
N½					1,280*					1,531*						
E½						1,275	1,217		1,320†			1,205			1,329	
14		1,414			1,278*					1,524*		1,181	1,159			
N½		1,424								1,516*						
E½										1,506*		1,182	1,166			
15		1,429*				1,251		1,266		1,492*						
N½		1,435			1,265					1,447*						
E½					1,319	1,271	1,219	1,271					1,202			
16	1,415	1,440		1,381*	1,240		1,278			1,425*						
N½	1,426	1,420								1,412*						
E½				1,415*	1,301		1,294	1,282								
17	1,415	1,410			1,249		1,237	1,292		1,403*			1,253		1,157	
N½	1,405	1,393								1,394*						
E½							1,251	1,282								
18	1,408	1,406					1,236	1,302		1,384*						
N½		1,418														
E½							1,241	1,307		1,382*						
19	1,395				1,210	1,190	1,219	1,260			1,260		1,360			
N½						1,172	1,215	1,262			1,249				788	
E½							1,239	1,280								
20	1,405	1,355			1,120	1,215	1,229	1,292†			1,270		1,283		1,125	
N½	1,403					1,205	1,214	1,269			1,265					
E½		1,385			1,280		1,228	1,280								
21	1,387			901†	929†	1,200	1,168	1,260			1,313	1.146	1,233		1,152	
N½						1,203	1,228				1,296					
E½	1,407			1,332*	1,255							880				
22		1,347				1,153	1,228	1,209			1,378	1,170	1,198		1,178	
N½						1,187	1,178				1,335	1,155			1,164	
E½		1,384			1,252	1,225	1,291									
23					830*	1,213	1,166	1,233			1,382	1,194	1,109		1,266	
N½						1,215	1,229					1,187			1,194	
E½					1,287*							1,192	1,157			

24		1,389	1,366		843	1,202	1,162	1,221			1,397	1,226	1,150	1,388	1,345	1,038†
N½							1,153	1,222			1,387	1,213				
E½		1,402	1,398		1,267	1,225	1,191	1,237	1,130†		1,388	1,218	1,149		1,334	1,030
25		1,351*	1,325*		1,041*		1,197	1,043	1,291			1,250			1,338	903†
N½		1,349*			1,094*											
E½			1,340				1,213	1,210	1,004			1,235			1,308	
26		1,350*			1,044*	835	1,212									
N½					1,158*											
E½							1,170									
27	1,396*	1,338			1,063*	939	1,217	1,230				1,185				
N½	1,393*															
E½		1,342				1,217	1,233	1,249								
28	1,296				900	1,070	1,036	1,235				1,151				
N½																
E½	1,149			838*			1,190	1,260								
29	1,278	1,321				1,027	1,260	1,239							1,145	
N½	1,373*															
E½	1,398	1,332					1,224	1,268							1,124†	
30	1,373	1,326*				988	1,189									
N½	1,371*	1,324*														
E½	1,390					1,187†	1,203									
31	1,198†	1,304*	1,274	1,367*	1,215*	811*	969*	1,269*				813				
N½				1,426*	1,095*	813*		1,287*				828				
E½	1,347*	1,310													818	
32	1,223	1,311	1,284	1,435,	1,302*	815*	1,181*	1,249*				1,108			1,146	
N½		1,309			1,284*	811*	1,175*	1,233*							1,135	
E½	1,043	1,316					1,255								1,147	
33	1,387*	1,324	1,284	1,328*	1,341*		927*	1,235*				1,160			1,166	
N½	1,355	1,318		1,427*	1,321*	831*	1,186*	1,248*				1,142			1,163	
E½	1,356*			1,378*	1,280											
34	1,405*	1,325	1,287	1,371*	1,363*	830*	1,010*	1,036*				1,169			1,175	
N½		1,326		1,338*	1,361*	831*	1,168*	1,229							1,171	
E½	1,409*	1,333			1,346		1,182									
35		1,338*	1,280	947*	1,225*	835*	941*	1,200*				1,224			1,242	
N½		1,333	1,290	1,142*	1,345*	837*	1,188*	1,216*				1,190			1,194	
E½		1,340*			1,167		1,205	1,210								
36			1,302	840*	1,408*	928*	805*	1,191*	1,297*			1,269	988		1,345	798†
N½				844	1,389	850	807	1,194				1,240			1,346	
E½			1,307		1,372			1,155	1,225			1,246			1,342	820†

TABLE VI

Tables of Elevations in the McMurray Area—*Con.*

Sec.	Township 91			Township 92			Township 93		Township 94			Township 95		
	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11	Range 10	Range 11	Range 10	Range 11	Range 12	Range 10	Range 11	Range 12
1	1,300	1,080†					1,056	1,011	1,070	832		995	779	1,052
N¼										898			881	
E¼		1,099				1,078	1,052	1,012	1,086			1,013		1,055
S.E.1		1,110										1,022		1,057
2							920						1,004	
N¼										968				
E¼							833						989	
3										1,032			981	
N¼														
E¼										1,036				
4					1,074				980				984	
N¼									882					
E¼														
S.E. 4													829	
5					1,044				866	1,086				
N¼									854					
E¼														
S¼	942												1,036	
6					1,032		1,016		856	1,085				
N¼														
E¼														
S¼	798												1,052	
S.E. 6														
7		1,163			1,010		1,039		874	1,070				
N¼	802				1,031									
E¼														
8	1,115	1,118			1,056		1,039		903	1,078				
N¼					1,023		1,035			1,085				
E¼										1,082				
9	1,142	1,097							992				981	
N¼					1,083				911					
E¼									993					
10	1,134	1,094			1,082					1,007			976	
N¼	1,129	1,092			1,072		777							
E¼					1,083					1,016				
11	1,168	1,100					1,038			864			977	
N¼		1,098			1,090		884			957				
E¼													984	

12	1,237					1,043	1,074	1,009	1,065		1,003	945		1,037
N¼	1,207	1,105			1,059		1,055			792				
E¼	1,256					1,059	1,073	1,009				980		
13	1,292		1,150			1,019	1,082	995	1,070	850	1,052	927		1,029
N¼									1,061					
E¼			1,171				1,080	994		813	1,063	929		1,036
14		1,058					1,052		1,050				880	
N¼									1,032					
E¼		1,099											953	
15	1,125	1,083					840		1,017	976			974	
N¼									1,019					
E¼							822							
16		1,076							997					
N¼									922					
E¼														
17	1,108	1,090			1,036				910	1,041				
N¼									899	1,043				
E¼		1,101			1,039									
18		1,117			1,020		1,036		903	1,039				
N¼									895	905				
E¼					1,017		1,048		892					
19	792	1,102			1,016		869		909	1,034				
N¼							897		907					
E¼					1,005†									
20	1,109	1,076			1,063				911	1,019				
N¼	1,012				1,047		825		905					
E¼		1,086							913					
21	1,125	960			1,063				963	1,012				
N¼	1,118				1,063				936	1,016				
E¼		1,028							984					
22	1,142	1,025			1,058		1,000		1,016	966			965	
N¼	1,131				1,067		999		998					
E¼		1,066			1,058					988				
23	1,184	1,047			878		1,059							
N¼	1,159	925			1,019								953	
E¼													765	
24	1,272	793	1,126			1,007		997	1,074	829	1,054		833	1,029
N¼	1,213				781				988†				803	
E¼	1,301		1,132			1,010	1,085	992		828			871	1,029
25	1,247		1,101				1,100	886			1,047	995	917	
N¼													864	
E¼	1,253					989	1,098	885	1,077	827		938		1,024
26		1,086												
N¼													822	
E¼		1,073												
27		1,051			1,005								960	
N¼													962	
E¼	1,242	1,068			1,053		1,018†			971				

TABLE VI

Tables of Elevations in the McMurray Area—*Con.*

Sec.	Township 91			Township 92			Township 93		Township 94			Township 95		
	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11	Range 10	Range 11	Range 10	Range 11	Range 12	Range 10	Range 11	Range 12
28		1,052			1,062		894†			995			969	
N½										1,002				
E½							887†						974	
29		1,053							913					
N½									904					
E½					1,056		828		907					
30		1,078			1,045		823		916	1,030				
N½														
E½	797	1,089			1,037					1,029				
31	795	1,055		1,077*	1,030*	1,130*		1,097	910	1,021			1,000	
N½		1,064		1,063*	1,022*	1,148*	805	1,085					1,010	
E½	780	1,041								1,023				
32	1,092	1,025		1,117*	1,037*	1,116*	877	1,084		1,001			986	
N½		1,048		1,102*	1,036*	1,134*	890	1,092					990	
E½							875							
33	1,199	1,062		1,162*	1,004*	1,086*	1,007	1,063	937	989			901	
N½	1,119			1,141*	1,042*	1,102*	889	1,078	917				983	
E½													961	
34	1,160	1,047		1,176*	779*	1,053*	1,032	1,041		990			905	
N½	1,142			1,169*	828*	1,068*	1,025	1,058					779	
E½													935	
35	1,203	1,099		1,219*	838*	1,002*	1,061	906	1,008				767	
N½	1,175			1,181*		1,040*	1,048	993	996					
E½														
36	1,306		1,090	1,269*	1,054*	1,023*	1,096	803	1,030			969	956	1,036
N½	1,214	1,079		1,237*	963*	984*	1,090	878				960	914	
E½	1,272		1,102			996	1,101	880				958		

Sec.	Township 96			Township 97			Township 98			Township 99			Township 100		
	Range 10	Range 11	Range 12	Range 10	Range 11	Range 12	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11
1		962	1,023	1,152	909	1,027		1,010	907	1,009	825	972	969	864	
N½											851		928		
E½	970		1,023	1,149	935	1,033						969		770	
S.E. 1										1,010		960			
2		920			833			985					921	784	
N½					889									865	
E½		880													
S.E. 2										995					
3					891			968			912		859	898	
N½					884								856		
E½					892										
S.E. 3										1,001					
4		933		1,136				924		975	924			904	
N½				1,165				868					753		
E½				1,140										916	
S.E. 4										977					
5				1,177						957	915				
N½				1,135				840		944			860		
E½											911				
S.E. 5										957	906				
6				998						922			861		
N½													857		
E½				944						908			854		
S.E. 6										940					
7		797		1,035				869		835			824		
N½				900											
E½		984											854		
8				1,081				798					867		
N½													861		
E½				1,072				838			918				
9		901		1,012	1,022					966	921		770	921	
N½															
E½		923		1,065	902			900		964	932				
10		805			903			950			935		762	909	
N½		827									919		758	911	
E½					905			950			934		748		
11		917			860			971					886	897	
N½					881									899	
E½					850			976					910	906	

TABLE VI

Tables of Elevations in the McMurray Area—*Con.*

Sec.	Township 96			Township 97			Township 98			Township 99			Township 100		
	Range 10	Range 11	Range 12	Range 10	Range 11	Range 12	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11	Range 9	Range 10	Range 11
12	983	953	1,024		806	1,041		967	913	1,015	864	981	924	876	
N½		934									862		922		
E½		966	1,024	1,122	855	1,032			911		835	976	948		
13		947	1,017		820	1,051		974	927	1,003	798		908	942	
N½		941						960					754		
E½			1,022			1,053		972			858			871	
14		924			867			952*					753	918	
N½					1,000						933				
E½		916			859			927					749	908	
15		857			1,078			937			927		750	908	
N½		882			1,084			773			928		796		
E½								942			928		765		
16		919		993	1,087			845		865	924			919	
N½		917		992				845		866			833		
E½		808		998	1,104						922			922	
17		934		991				844		842			837		
N½		964		981				876		840			765		
E½				1,009									852		
18		979		907				906		848			866		
N½		993		831				909					882		
E½		977		983				891							
19		953		825				887		838	943		977		
N½				825				924		830			943		
E½		963		877				903							
20		929		961				868		829	929		833		
N½		964						911		801	937		865		
E½		931								838			758		
21		933		992	1,008					872	930				
N½		913		973				845		882			762		
E½		929		994	1,042					863					
22		870			1,055			759			946		832	913	
N½		880			1,076						919				
E½					1,070			878			942			915	
23		851			924			951			919			908	
N½					1,053						916			931	
E½		914			905						925		746		
24	1,101		1,002	985		1,058	979	954	938	996		968	778	935	986
N½														918	
E½			990						933				913		983

25	1,101	954	1,030	1,008	865	1,052	1,003	940	922	994	788	973	828	886	990
N¼		941			894								758		
E¼			1,016	990		1,030	986		938	994		972	793		985
26					935			910			909		750		
N¼		860			1,001						933				
E¼					928			955			932				
27		881			1,006			823			923		821	911	
N¼		894			972						916			913	
E¼		878			1,014						917		827	917	
28				987	974			846		857	913		857	921	
N¼				977						855			861		
E¼				991	976										
29				936				918		779	920		896		
N¼				833				918		821	932		890		
E¼				947				917					833		
30								917					875		
N¼											961		878		
E¼				825				908		785					
31	934*	985*			1,024			921					870*	971*	
N¼	940*	1,004*			1,038			959					876*	987*	
E¼								919							
32	1,063*	951*		936	995			917			922		849*	944*	
N¼	995*	966*			1,014								887*	960*	
E¼				911*				925			923		894		
33	1,140*	913*		970	967			889		877	919		844*	929*	
N¼		920*		943	987			912		863	911		772*	931*	
E¼	1,135*			990						854	918			923	
34	1,152*	884*		1,000*	968					965	901			906*	
N¼	1,150*	911*		1,000*						860	910		860*	912*	
E¼		878													
35	1,138*			1,007	925			830		939	906		743*	893*	
N¼	1,127*				964					881			737*	904*	
E¼					944			838			909				
36	1,139*	943*	1,024*	1,014	897	1,063	1,012	930	948	989			899*	884*	1,003*
N¼	1,120*	863*			922					988	884		878*	869*	
E¼	1,112	936	1,021	1,010	876	1,056	1,013		940	984			866		998

Other elevations[1] not included in the above tables are as follows:—

	feet
Intersection of Alberta and Great Waterways railway—	
With N. boundary sec. 33, tp. 87, R. 7	1,316*
With N. boundary sec. 5, tp. 88, R. 7	1,301*
With E. boundary sec. 7, tp. 88, R. 7	1,294*
With E. boundary sec. 13, tp. 88, R. 8	1,255*
With E. boundary sec. 23, tp. 88, R. 8	1,192*
With E. boundary sec. 22, tp. 88, R. 8	1,137*
With N. boundary sec. 22, tp. 88, R. 8	1,127*
With E. boundary sec. 28, tp. 88, R. 8	1,063*
With E. boundary sec. 29, tp. 88, R. 8	977*
With N. boundary sec. 29, tp. 88, R. 8	869*
With E. boundary sec. 31, tp. 88, R. 8	834*
Elevation Waterways station (sec. 31, tp. 88, R. 8)	821*
Water level, Athabaska river—	
23rd base line (Sept. 19, 1911)	816*
24th base line (July 18, 1913)	773*
25th base line (Dec. 17, 1923)	751*
26th base line (July 10, 1914)	736*
B.M. 83, 24th base line, E. side Athabaska river, on mark "T" on boulder, a little over ½ mile east of water's edge and 371 feet east of mound at N.E. cor. sec. 35, tp. 92, R. 10	839*
B.M. 84, 24th base line, W. side Athabaska river, on top of iron post marked "B.M. 84," 42 feet west of water's edge and 1,118 feet east of mound at N.E. cor. sec. 34, tp. 92, R. 10	785*
B.M. 91, 25th base line, W. side Athabaska river on top of iron post marked "B.M. 91," 729 feet west of water's edge and 198 feet west of witness mound	764*
B.M. 84, 26th base line, W. side Athabaska river, on top of iron post 990 feet west of N. ¼ cor. sec. 34, tp. 100, R. 9	863*
Wt. I.T.M. 5 S., east side sec. 13, tp. 88, R. 7	1,086
Wt. I.T.M. 1 S., L.S. 1, sec. 13, tp. 90, R. 10	1,092
Wt. I.T.M. 1 S., L.S. 9, sec. 13, tp. 90, R. 10	1,092
Wt. I.T.M. 10 E., north side sec. 19, tp. 90, R. 9	786
Wt. I.T.M. 1 N., east side sec. 31, tp. 90, R. 9	1,066
Wt. I.T.M. 3 E., north side sec. 7, tp. 91, R. 9	797
Wt. I.P.M. 2 N., east side sec. 10, tp. 92, R. 10	1,079
Wt. I.P.M. 5 N., east side sec. 29, tp. 92, R. 10	1,056
Wt. I.P.M. 2 S., east side sec. 13, tp. 93, R. 10	1,077
Wt. I.P.M. 10 W., north side sec. 11, tp. 93, R. 10	817
Wt. I.P.M. 7 E., north side sec. 9, tp. 93, R. 10	779
Wt. I.P.M. 13 E., north side sec. 34, tp. 93, R. 10	1,031
Wt. I.P.M. 5 W., north side sec. 32, tp. 93, R. 10	812
Wt. I.T.M. 1 E., north side sec. 32, tp. 94, R. 10	917
Wt. I.T.M. 1 S., east side sec. 23, tp. 94, R. 11	786
Wt. I.T.M. 9 N., east side sec. 25, tp. 94, R. 11	785
Wt. I.T.M. 11·5 E., north side sec. 35, tp. 96, R. 11	768
Wt. I.T.M. 4 S., east side sec. 25, tp. 97, R. 11	786
Wt. I.T.M. 10 S., east side sec. 8, tp. 98, R. 10	829
Wt. I.T.M. 13 N., east side sec. 9, tp. 98, R. 10	954
Wt. I.T.M. 4 W., north side sec. 26, tp. 98, R. 10	758
Wt. I.T.M. 4 W., north side sec. 27, tp. 98, R. 10	834
Wt. I.T.M. 9 E., north side sec. 35, tp. 98, R. 10	826
Wt. I.T.M. 2 S., east side sec. 7, tp. 99, R. 9	846
Wt. I.T.M. 5 E., north side sec. 21, tp. 99, R. 10	921
Wt. I.T.M. 10 S., east side sec. 28, tp. 99, R. 10	915
Wt. I.T.M. 1 E., north side sec. 31, tp. 99, R. 9	751
McMurray Townsite—	
S.W. corner river lot 7, (foot of 1. P.)	825
W. I.P.M. 4 E., south side river lot 9	1,032
S.W. corner river lot 11 (foot of 1. P.)	1,042
S.W. corner river lot 14 (foot of 1. P.)	1,035
Water level Clearwater river, river lot 19 (Oct. 15, 1924)	792
Intersection west side river lot 8 with south side Franklin Ave	821

[1] Elevations determined by Topographical Surveys Branch, Dept. of the Interior, are indicated thus (*). Elevations along Alberta and Great Waterways railway refer to top of rail.

Sections

Using a vertical scale of one inch equals 200 feet, and a horizontal scale of one inch equals one mile, a series of East-West sections has been prepared.[1] The area illustrated by these sections extends from the south boundary of township 88, to a point two miles north of the south boundary of township 98. Beyond this northern limit, major exposures of bituminous sand are not seen near Athabaska river. Surface profiles across the northern portion of township 98, and across townships 99 and 100, are not included in the above series, but are marked by uniform decrease in elevations. Thus, on the 26th base line, (north boundary of township

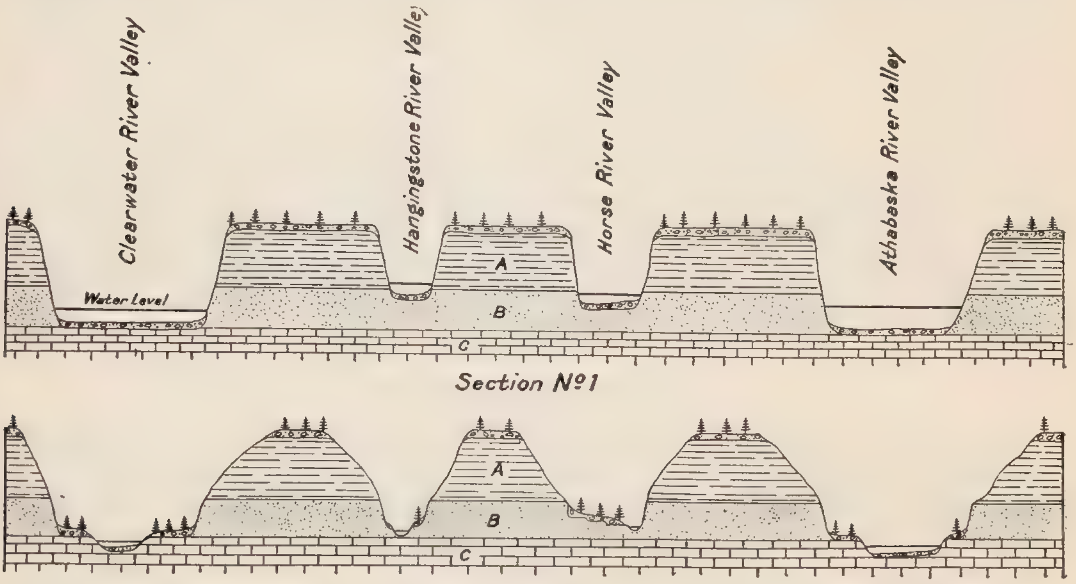

Fig. 2.—Diagrammatic East and West sections in township 89, range 9. Section 1 illustrates an earlier period of erosion, while section 2 illustrates present conditions under which diminishing streams have left residual benches or terraces of bituminous sand. (a) Cretaceous shales and sandstones; (b) Bituminous sands; (c) Devonian limestones and shales.

100), maximum elevations at points 6 miles east and west of Athabaska river, are but 962 and 906 feet respectively. Where base lines and subdivision survey lines were available, surface profiles have been plotted largely from the writer's levelling records. Where such lines were not available, elevations have of necessity been projected from the writer's topographical maps.

The position of bituminous sand strata[2] and of underlying limestone indicated on the above sections, is based on elevations of upper and lower limits of bituminous sand, as observed along Athabaska river and tributary streams. Pending detailed exploration by means of core-drilling,

[1] These sections are published on a reduced scale. Blue-prints from original tracings may be secured on payment of cost of blue-printing.

[2] During 1913 and 1914 numerous detailed sections were prepared, and on these were indicated relative proportions of high-grade and low-grade bituminous sand. These are not included in the present report as they can only prove misleading.

Particularly in the southern portion of the McMurray area, a variable thickness of bituminous sand as indicated on the various general sections included with this report, is of such a low grade as to be of no commercial value and must be classed as overburden. It has not been possible, however, to differentiate this from the richer portion of the deposit.

sections projected for considerable distances on incomplete data at present available, must be considered as general approximations. This is particularly true within those areas (as in townships 93 and 94) where pronounced folding and probable faulting has taken place, in addition to erosion. Where lower limit of bituminous sand lies at an elevation lower than water level of Athabaska river, the indicated total thickness of the bituminous sand strata is largely conjectural. Nevertheless, considering the importance which will probably attach to the overburden factor, the sections indicate the general position of those areas which are best adapted to extensive commercial development. It is considered, moreover, that the profiles will be of practical value, as bases on which to record such further data as future and more detailed work may discover from time to time.

Special Surveys

Firebag river has been traversed for a distance of approximately 60 miles from its junction with Athabaska river, and a geological section projected. Clearwater river has been traversed easterly to the mouth of High Hills river. A detailed topographical map[1] of McMurray settlement was prepared by C. H. Freeman and has been drawn on a scale of 1 inch equals 400 feet. On this map contours having an interval of 10 feet, lot subdivisions and buildings have been indicated.

Special Maps[1]

(*a*) A general map of the McMurray area extending from township 88 to township 100 has been drawn on a scale of 1 inch equals 2 miles. On this map contours having an interval of 100 feet are shown. Outcrops of bituminous sand have been provisionally classified and their positions indicated.

(*b*) A general map of the McMurray area has been prepared on a scale of 1 inch equals 2 miles. On this, the positions of 23 of the more promising areas of bituminous sand have been provisionally shown.

III. SHIPMENTS OF BITUMINOUS SAND

At various times, as required, small shipments of bituminous sand, aggregating approximately 140 tons, have been mined and utilized in connexion with experimental work.[2] The greater part has been excavated and shipped in sacks from outcrops on Horse river (sec. 8, tp. 89, range 9); Clearwater river (sec. 14, tp. 89, range 9); and Athabaska river (sec. 24, tp. 95, range 10). During the summer of 1924, approximately 10 tons of bituminous sand was mined by shafting, and shipped in barrels and sealed gasoline tins. A portion of this material was stored with Mr. A. Norquay, Dominion Lands Agent, Department of Interior, Edmonton, and is available for those who may require small quantities in connexion with experimental work.

[1] These maps will be reproduced as blue-prints only.

[2] In addition to bituminous sand mined by the writer, approximately 343 tons has been shipped by the McMurray Asphaltum and Oil Company, from Waterways, Alberta. All other shipments combined probably do not exceed 50 tons, so that the total amount of bituminous sand shipped from the McMurray area up to December 1924, is approximately 530 tons.

IV. DEMONSTRATION PAVING[1]

In view of the many failures and serious financial losses which had attended the earlier attempts in the United States to utilize somewhat similar bituminous sands in connexion with paving construction, the writer suggested in 1913 that a demonstration pavement be laid in Edmonton with McMurray bituminous sands. It was felt that to handle this untried material in a haphazard manner, either through failure to intelligently appreciate its true nature, or through lack of proper manipulation, would simply be to court failure. Accordingly, in August and September, 1914, a shipment of approximately 60 tons was mined and sacked. During the winter of 1914-15, 23 teams broke a road to McMurray, via Athabaska River and Horse River trails—a distance of nearly 250 miles—and returned with the 1,200 sacks of bituminous sand to the railhead at Athabaska.

SITE OF DEMONSTRATION PAVEMENT

As a site for the proposed pavement, a section of Kinnaird street, immediately south of Alberta avenue, Edmonton, was selected. The traffic along this portion of Kinnaird street may be classed as fairly heavy, including as it does a considerable volume of fast automobile traffic, and other vehicles carrying loads up to 10 tons.

SELECTION OF BITUMINOUS SAND

In the preliminary reconnaissance work already referred to wide variation in the grading of the mineral aggregate was clearly recognized.[2] This variation characterized not only separate outcrops, but was also observed within comparatively narrow limits in individual outcrops. Similarly, it was early recognized that very considerable variation would be found in the percentage of the bitumen content. Unimpregnated partings of clays, lignite particles, gravel, and other undesirable material, constituted another feature to be carefully considered.

During the field season of 1913, and over an area exceeding 750 square miles, upwards of 250 separate outcrops of bituminous sand had been noted. In the selection of this trial shipment very considerable care was required; more particularly in an entirely undeveloped and largely unexplored field. This fact has been emphasized by the results of the reconnaissance of the previous year, and in a report[3] prepared in 1913, various outstanding features were briefly discussed.

At the outset it was possible to eliminate a number of the recognized outcrops from further consideration. In so doing, the results of the analyses of samples secured in 1913, and obvious transportation difficulties in handling the contemplated trial shipment served as a basis.

In mining a trial shipment it was deemed desirable that the outcrop or outcrops selected should be such as might, later on, lend themselves to

[1] Mullen, Charles A. "Paving Economy." Industrial and Educational Press, Montreal, 1917.
[2] For discussion of the theory of sheet asphalt mixtures, see "Laboratory Investigation of a New Theory of Sheet Asphalt Paving Mixtures;" MacNaughton, M. F., Published by Milton Hersey and Co., Montreal.
[3] Mines Branch No. 281. Preliminary Report on Bituminous Sands of Northern Alberta. S. C. Ells.

development on a commercial scale.[1] Any results obtained through the use of material from unworkable deposits, might obviously convey an entirely wrong impression as to the probable economic value of the deposits as a whole.

In undertaking the examination of those deposits which appeared to conform to the requirements determined upon, the overburden was first removed by pick and shovel, supplemented at times by use of explosives. Specially designed augers[2] were then sunk to the required depth, in 12- to 14-foot lifts, and an accurate core sample thus obtained. The entire core was then placed in a rotary mixer, and thoroughly mixed. An 8- to 10-pound sample was then taken from the mixer, and gently warmed in a large iron pot. As the material became softened, it was further mixed by constant agitation with a large metal spoon. Finally, a sample of 150 to 250 grammes was taken for analysis.

As the result of a series of tests made in the laboratory in Ottawa, it appeared that the bitumens extracted from samples of bituminous sand from various parts of the McMurray area, did not differ greatly in their chemical and physical characteristics. Consequently the only tests made in the field comprised careful screen analyses of the mineral aggregate, together with a determination of the approximate percentage of associated bitumen. In all about 72 samples were tested during the field season by the use of simple portable apparatus.

It should be remembered that deposits of bituminous sand in northern Alberta may be roughly grouped in two classes, viz:

(*a*) Deposits in which bitumen is combined with a coarse mineral aggregate.

(*b*) Deposits in which bitumen is combined with a fine mineral aggregate.

The trial shipment of bituminous sand shipped from McMurray to Edmonton comprised both fine-grained and coarse-grained varieties.

A study of preliminary analyses at once indicated the necessity for careful manipulation of the crude material, both before and after it was placed on the street.

The following is a very brief outline of the procedure followed in laying the above pavement.

[1] In choosing the outcrops from which bituminous sand was eventually taken, it has been assumed that they are adapted to commercial development. Only careful and systematic prospecting with suitable equipment will, however, definitely determine their true value.

[2] For complete descriptions see Mines Branch No. 281, Preliminary Report on Bituminous Sands of Northern Alberta, 1913.

MANIPULATION OF BITUMINOUS SAND BEFORE BEING SENT TO STREET

For convenient reference, abridged analyses of the crude bituminous sand may be stated as follows:—

—	Coarse bituminous sand	Fine bituminous sand
	per cent	per cent
Asphalt	12·0	16·0
Passing 200	2·7	6·0
" 100 screen, retained on 200 screen	4·5	54·6
" 80 " " 100 "	0·7	15·6
" 50 " " 80 "	6·8	23·0
" 30 " " 50 "	22·0	0·6
" 20 " " 30 "	34·2	....
" 10 " " 20 "	27·2	....
Oversize	1·6	....

Penetration of Extracted Bitumen

Penetration at 115° F., 100 grms., 5 secs	too soft
" " 77° F., 100 " 5 secs	too soft
" " 77° F., 100 " 1 sec	130° Dow
" " 32° F., 100 " 5 secs	25° Dow
Ductility at 77° F	100 cm.+
Volatile 160° C.—5 hours (using New York testing oven)	11·2%
" 205° C.—5 " " "	14·2%
" 250° C.—4 " " "	18·8%

From a consideration of the above analyses of the crude material, three outstanding features are at once apparent:—

(1) High penetration of asphalt cement (due to presence of low-boiling fractions).

(2) Unbalanced mineral aggregates.

(3) Excess of asphalt cement.

The effect of unduly high penetration was modified by partial distillation of the more volatile fractions. The unbalanced aggregates of coarse and fine bituminous sand were partly corrected by combining the two in a proportion of two fine to one of coarse. In the case of the sheet asphalt[1] mix, the resulting aggregate was further modified by the addition of clean and graded sand; but in the case of the bitulithic mix,[2] by the addition of clean sand and graded crushed gravel. In the case of the bituminous concrete,[2] fine-grained bituminous sand only was used, which was modified by the addition of graded crushed gravel, and clean sand. This manipulation also reduced the somewhat high percentage of asphalt cement present in the original material, to the final percentage desired in each case. Figure 3 illustrates type of mixer used by the writer in preparing experimental mixes for street and sidewalk surfacing. Figure 3A illustrates type of adjustable mould used in forming experimental blocks.

In heating and mixing materials for the pavement itself, a heated rotary mixer (Plate XXI) was used. This mixer consists essentially of a revolving jacketed drum, set on trunnions above a firebox, and connected

[1] Brochure No. 9, The Asphalt Association, New York.

[2] "Asphaltic Concrete," Brochure No. 10, and "Asphalt Paving Mixtures," Brochure No. 11; The Asphalt Association, New York.

to the engine by shafting and gears. The inner surface of the mixer drum is fitted with baffles so arranged that a thorough mixing of charged materials is assured. Convenient charging and dumping facilities are provided.

In the experimental work here referred to, the mixer used proved fairly satisfactory. In heating and mixing Alberta bituminous sand on a com-

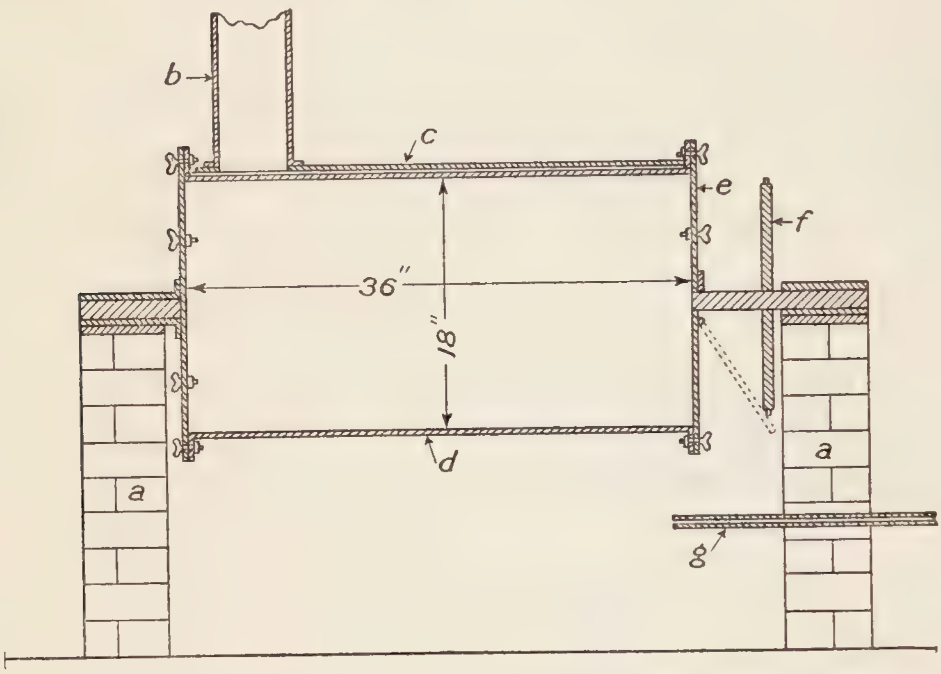

Fig. 3.—Heated mixer used in preparation of experimental paving mixes; a, brick wall; b, flue; c, 3/16-in. metal hood; d, 3/16-in. flanged iron mixing drum; e, end plates secured by pinch screws to drum flanges; f, driving sprocket; g, oil burner.

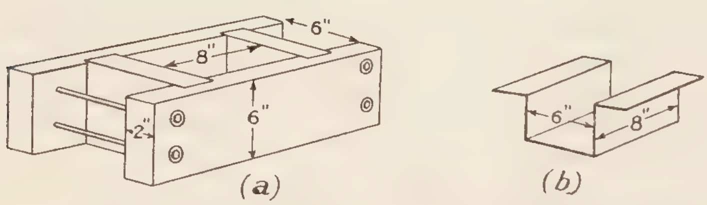

Fig. 3A.—Collapsible mould for experimental paving mixes. (a) is wooden mould made from 2-in. x 6-in. dressed scantling and held together by ½-in. iron rods. (b) is heavy galvanized iron form which fits inside mould (a). The ends are open.

mercial scale, however, the limited capacity of the mixing drum would render its use impracticable. A Torpedo mixer somewhat similar to those used by the City Street Improvement Company of San Francisco, should give satisfactory results when large throughput is required.

In actual operation, and prior to charging, the drum was usually preheated to a temperature of 250° to 300° F. The bituminous sand was then wheeled in barrows to the loading-platform, and the drum charged. During the first period of heating the charging opening of the drum was kept closed by means of a damper. When, however, the bituminous sand had reached the desired temperature, the heat was turned off and the damper removed. The mix was then allowed to remain in the drum for a further period of 8 to 10 minutes, during which time the lighter hydrocarbons passed off freely as vapour.

In adding crushed rock—as in the case of bituminous concrete and bitulithic mixes—it was found that a better bond resulted when the rock was charged at a drum temperature not above 300° F. In adding new sand, however, as in the case of sheet asphalt, the sand was usually added after the crude bituminous sand had attained a temperature of 380° to 400° F. In either case it was found that a period of 10 minutes was sufficient to permit of all materials becoming thoroughly mixed. The following abridged record sheet indicates average periods of heating, range of temperatures, weights and composition of mixes.

Charge Sheet of Mixture Averages

Charge	Sheet asphalt		Bituminous concrete		Bitulithic	
	Lbs.	%	Lbs.	%	Lbs.	%
Fine-grained bituminous sand	726	52·5	755	58·0	480	35·0
Coarse- " " "	363	26·5	....	....	240	17·5
10/20 clean sand	....	....	52	4·0	26	1·9
30/50 "	114	8·2	....	....	....	....
50/80 "	77	5·6	....	....	....	....
Dust (Portland cement)	100	7·2	....	....	26	1·9
Crushed gravel (crusher run), max. ½ inch	....	....	388	29·8	....	....
" " $\frac{1}{10}$–$\frac{1}{8}$ inch	....	....	....	....	16	1·2
" " $\frac{1}{8}$–$\frac{1}{4}$ inch	....	....	....	....	70	5·1
" " $\frac{1}{4}$–$\frac{1}{2}$ inch	....	....	107	8·2	156	11·4
" " $\frac{1}{2}$–$\frac{3}{4}$ inch	....	....	....	....	248	18·1
" " $\frac{3}{4}$–1 inch	....	....	....	....	108	7·8
Total weight in charge	1,380	....	1,302	....	1,370	....

In each case the crude bituminous sand was heated alone for a period of from 20 to 30 minutes. The clean sand, or the clean sand with crushed gravel, was then added. This addition caused the temperature of the mix to fall 20 to 30 degrees, and 5 to 8 minutes were required for the mix to regain its former temperature. The damper was then removed from the mixer drum and vaporization of the lighter hydrocarbons—indicated by volumes of oil vapour—proceeded freely. To some extent, the colour of the vapour indicated the progress of distillation, but after a period not exceeding 10 minutes the contents of the drum were discharged into a wagon. The average time required for the treatment of a 1,400-pound

batch (equivalent to approximately 7 square yards of 2-inch surface) was thus rarely less than 40 minutes, and it is doubtful whether much better average results could be hoped for with the equipment used. The temperature of the mix when discharged into the wagons, usually ranged from 380° to 410° F.

The following are abridged analyses[1] of samples taken from wagons:—

—	Sheet asphalt	Asphalt concrete	Bitu-lithic
	per cent	per cent	per cent
Through 1 inch and retained on 10 mesh	....	....	34·7
" ½ inch and retained on 10 mesh	....	35·3	....
Retained on 10 mesh	0·5	....	....
Through 10 mesh, retained on 20 mesh	7·0	4·0	6·7
" 20 " " 30 "	12·5	0·8	8·1
" 30 " " 50 "	13·5	0·3	....
" 50 " " 80 "	13·7	4·2	....
" 80 " " 200 "	33·0	42·1	37·0
" 200 " "	9·0	3·9	5·2
Asphalt cement	11·3	9·1	8·1
	100·5	99·7	99·8

Penetration of asphalt cement at 115° F., 100 grms. 5 secs	too soft
" " " 77° F., 100 grms. 5 secs	too soft
" " " 77° F., 100 grms. 1 sec	120° Dow
" " " 32° F., 100 grms. 5 secs	19° Dow
Ductility " " 77° F.	100 cm. +
" " " 115° F.	100 cm. +
" " " 32° F.	100 cm. +

Penetration of the asphalt cement extracted from different batches, after heating, varied considerably, the lowest being 85° Dow, (77° F., 100 grammes, 5 seconds). Owing to engine trouble, the mix from which this particular sample was taken, was held in the mixer for upwards of one hour.

The consistency of the asphalt cement extracted from certain other samples indicates insufficient heating. This is undoubtedly a weakness. It is, however, not believed that it will result in the disintegration of the wearing surface, although the surface may mark excessively in warm weather. The readiness with which a soft pavement takes up the surface dust carried on it, as well as the evaporation of the lighter oils, will result finally in curing the defect. With a modified type of mixer especially adapted to handling the Alberta bituminous sand, there is but little doubt that the lack of uniformity and defects noted above can be corrected.

In the balancing of the various aggregates, the above analyses indicate room for improvement; and in this respect there should be no real difficulty in making desired modifications. The penetration of the asphalt cement is high. Within reasonable limits and with a properly balanced aggregate, this does not necessarily indicate a source of weakness.

[1] All analyses are by the writer, and are based on extraction by centrifuge.

Demonstration pavement laid in Edmonton, Alberta, under the supervision of S. C. Ells, Mines Branch, August, 1915.

Bituminous sand quarry operated by City Street Improvement Company, near Godola, Cal.

MANIPULATION OF BITUMINOUS SAND AFTER BEING SENT TO STREET

The subgrade upon which the base was laid was a typical prairie loam, on strong blue clay. After grading had been completed, it was thoroughly compacted by rolling with a 7-ton roller. The finished grade showed a maximum gradient of 1 per cent.

A 6-inch concrete base (composed of 1 part Portland cement, 3 parts clean, sharp sand, and 6 parts crushed gravel) was laid on the subgrade. In order that this base might thoroughly set, an interval of 11 days was allowed to elapse before the asphalt wearing surface was added.

The sheet asphalt was given a compacted thickness of 2¼ inches, and was laid on an open binder, compacted to 1½ inches. The bitulithic and bituminous concrete were laid directly on the concrete base, and were given a compacted thickness of 3 inches. A thickness of 2½ inches would probably have given as good results. The width of the finished pavement was 18 feet.

No permanent curb or other lateral support was available. Consequently tamarac headers 4 by 6 inches were used and were secured to stakes, 4 by 6 inches by 2 feet 6 inches. Headers of this type have been extensively used in Edmonton, and have given general satisfaction.

The wearing-surface mixture reached the street at an average temperature of 325° F., though the temperature of occasional loads was 350° F. It was immediately spread with hot shovels and hot rakes.

Owing to the somewhat light nature of the contained asphalt cement, it was found necessary to exercise care in rolling. The best results were obtained by first rolling with a light (15 pounds per linear inch width of tire) hand-roller almost immediately after the material had been spread. As soon as the temperature permitted—usually within three hours—a small quantity of Portland cement was sprinkled, and the surface thoroughly compacted by means of a 7-ton roller (250 pounds per linear inch width of tire).

In the case of the bituminous concrete and bitulithic, the usual flush coat, with ¼-inch stone screenings, was spread upon the surface, and all superficial voids filled.

The experimental pavement (Plate XXII) referred to above was opened to traffic on August 26, 1915, and its present condition is referred to in the following communication from Mr. A. W. Haddow, City Engineer, Edmonton, under date of February 10, 1925:—

> With regard to experimental paving on 82nd Street which was laid by you in 1915, I am glad to advise you that this has remained in excellent condition, and to date showns no signs of defect or deterioration, and seems to be good for many years of satisfactory service.

DEDUCTIONS BASED ON COSTS OF MATERIALS

In view of the conditions under which the above work was carried out, it is difficult to deduce definite cost data. Moreover, until definite freight tariffs are established[1] between the northern terminus of the

[1] In 1925, a freight rate of $2.25 per ton on coal was granted by the Alberta and Great Waterways Railway between Edmonton and Waterways.

Alberta and Great Waterways railway and various centres of distribution, it will be impossible to definitely determine the radius within which competition with imported oil asphalt will be possible. The following estimate, based on costs of materials (1925) in Edmonton, Alberta, furnishes a general comparison between (1) bituminous sand mixtures, and (2) mixtures in which clean sand, crushed gravel, and imported bitumen are used. The estimated value of the bituminous sand is deduced by subtracting the total value of other ingredients from the cost of one ton of mixture consisting of imported asphalt cement, combined with local sand and crushed rock.

Tabulation of the Costs of Material for Bituminous Mixture. Based on 1925 Prices delivered at the Edmonton Plant

Sand and Rock Mixtures with Imported Asphalt[1]

—	Bituminous sand	Clean sand at $1.44 per ton	Filler (Portland cement) at $20 per ton	Crushed gravel at $2.20 per ton	Asphaltic cement at $34.46 per ton	Total cost of material per ton of mixture
Sheet asphalt	....	82% $1.18	7% $1.40	....	11% $3.79	.... $6.37
Bituminous concrete	....	46% $0.66	4% $0.80	42% $0.92	8% $2.76	.... $5.14
Bitulithic	....	32% $0.46	4% $0.80	56% $1.23	8% $2.76	.... $5.25

Bituminous Sand Mixtures

—	Bituminous sand	Clean sand	Filler	Crushed gravel	Asphaltic cement	Total
Sheet asphalt	79% $5.98 $4.73	13·8% $0.20	7·2% $1.44	....	....	.... $6.37
Bituminous concrete	58·0% $7.31 $4.24	4·0% $0.06	....	38·0% $0.84	....	.... $5.14
Bitulithic	52·5% $7.39 $3.88	1·9% $0.03	1·9% $0.38	43·8% $0.96	....	.... $5.25

[1] For approximate calculations, it may be assumed that one ton of mixed materials is equivalent to 14·5 cubic feet, or 9·5 square yards of 2-inch compacted wearing surface.

From this estimate it appears that theoretically in competition with imported bitumen, combined with local sand and crushed gravel, $5.98, $7.31, and $7.39 may be paid for crude bituminous sand at point of delivery, when used in preparation of sheet asphalt, bituminous concrete, and bitulithic mixtures, respectively. If from these amounts mining costs and profit are deducted, the difference will represent the approximate amount per ton that may be paid in freight charges. In estimating the cost per square yard of finished surface, usual charges for unloading materials at plant, heating and mixing (including labour, teams, power, etc.), haulage to street, laying, and fixed charges (including repairs, inter-

est, superintendence, profit, and contingencies) must be added. No allowance has been made for possibly lower maintenance charges when bituminous sand is used. During 10 years, maintenance charges on the demonstration bituminous sand pavement referred to above, have been nil.

The problem of handling a material which rapidly consolidates on railway cars and in stock piles requires careful consideration.

In 1916, the writer secured from all municipalities in Manitoba, Saskatchewan, and Alberta, having a population of more than 10,000, statements of costs of materials entering into the construction of asphalt wearing surfaces. This data is now obsolete, but the following brief summary of (a) costs of materials (1925) and (b) freight rates (1924-25), will serve as a basis for a preliminary consideration of the possible radius of distribution for crude bituminous sand.

Cost of Materials F.O.B. Cars

—	Crushed sand		Crushed rock		Crushed gravel		Portland cement	Asphalt cement	Remarks
	Per ton	Per cu.yd.	Per ton	Per cu.yd.	Per ton	Per cu.yd.			
	$	$	$	$	$	$	$	$	
Winnipeg	......	1·45	......	3·25	......	......	18·00	29·00	A.C. in bulk.
Regina	1·75	......	2·75	......	......	......	22·85	41·00	" in bbls.
Saskatoon	1·66	2·50	2·66	4·00	1·66	2·50	19·73	43·51	" "
Edmonton	1·44	1·92	2·20	3·25	2·20	3·25	20·00	{34·46 {38·78	" in bulk. " in bbls.
Calgary	1·85	2·50	3·33	{2·50 {4·00	3·33	......	21·50	36·52	"
Jasper	1·25	......	......	......	......	......	15·66	....	
Banff	1·00	......	......	1·95	......	1·75	14·45	33·00	

DEDUCTIONS BASED ON FREIGHT RATES

Crude bituminous sand will be used largely in the surfacing of streets and highways, first cost and maintenance of which is reflected in taxes levied by municipalities. Freight charges will constitute an important item in cost of the bituminous sand as delivered. Since railroad companies contribute to the above taxes, it would appear to their advantage that freight rates be as favourable as possible.

At one time freight rates seriously restricted the movement and distribution of bituminous sand and other rock asphalts in the United States. Rates now in force (and quoted below) have resulted in material expansion of the rock asphalt market.

Freight Schedules Governing Movement of Kentucky Rock Asphalt (Bituminous Sandstone)

In column "A" are rates established by the Louisville and Nashville Railroad Company from Bowling Green, Ky., to all stations on its line. The same rates also apply from Illinois Central mines to points

on that system. In column "B" are shown rates from Memphis, Tenn.; Vicksburg, Miss.; and New Orleans, La., to points in Arkansas and Louisiana. The schedules are very similar.

	"A"	"B"
	Cents per 100 lbs.	
10 miles and under	4·5	4·5
20 miles and over 10	5·1	5·0
45 " " 20	5·65	6·0
65 " " 45	6·2	6·5
75 " " 65	7·35	7·0
85 " " 75	7·35	7·0
100 " " 85	7·9	7·5
110 " " 100	7·9	7·5
130 " " 110	8·45	8·5
140 " " 130	8·45	8·5
170 " " 140	9·0	9·0
200 " " 170	10·15	10·0
230 " " 200	10·7	11·0
250 " " 230	11·25	11·5
300 " " 250	11·85	12·5
350 " " 300	12·95	13·5
400 " " 350	13·5	14·5
425 " " 400	14·1	15·5
450 " " 425	14·65	15·5
475 " " 450	15·75	15·5
500 " " 475	16·35	15·5
550 " " 500	16·9	....
600 " " 550	17·45	....
650 " " 600	18·6	....

In the following table are shown rates from Louisville, Ky., to various points in the Central Freight Association territory. These particular rates are known as proportional rates, and the proportional rate from Bowling Green to Louisville of **$1.13** per net ton, must be added in order to establish a through rate.

Bituminous Rock, Louisville, Kentucky, to
(per ton of 2,240 pounds)

	Distance miles	
Buffalo, N.Y.	532	$3.91
Cleveland, Ohio	297	3.46
Detroit, Mich	381	3.34
Toledo, Ohio	316	3.00
Chicago, Ill	311	2.82
Indianapolis, Ind	111	2.19
Milwaukee, Wis	396	2.57

The above rates are approximately the same as those on sand and gravel.

Bituminous Rock, Louisville, Kentucky, to
(per ton of 2,000 pounds)

	Distance miles	
Atlanta, Ga	361	$3.60
Augusta, Ga	432	4.21
Macon, Ga	449	3.94
Charleston, S.C	669	4.68
Savannah, Ga	639	4.68
Jacksonville, Fla	710	4.68

Freight Schedule Governing Movement of Uvalde Rock Asphalt

Distances—miles	Single Line Rates per cwt.	Joint Rates per cwt.
	cts.	cts.
10 and under	3	3½
20 and over 10	3	3½
30 " " 20	3½	4
40 " " 30	3½	4
50 " " 40	4	5
60 " " 50	4	5
70 " " 60	5	5½
80 " " 70	5	5½
90 " " 80	5½	6½
100 " " 90	5½	6½
110 " " 100	5½	7
120 " " 110	6½	7
130 " " 120	6½	7
140 " " 130	7	7
150 " " 140	7	7
175 " " 150	8	8
200 " " 175	8	8½
225 " " 200	8	9
250 " " 225	8½	10
275 " " 250	9	10
300 " " 275	10	10½
350 " " 300	10½	11
400 " " 350	11½	12
450 " " 400	12	12½
500 " " 450	13½	13½
550 " " 500	14½	14½
600 " " 550	15½	15½
Over 600	16	16

Should it eventually be found possible to ship McMurray bituminous sand under the sand-gravel classification, the following statement of freight rates will furnish some indication of possible radius of distribution.

Rates per 100 pounds in Carload Quantities from Edmonton[1]

—	Distance	Bituminous sand	Common sand and gravel
	miles	cts.	cts.
To Red Deer	99	15	6½
Calgary	194	21	9
Banff	276	27	14
Bassano	271	24	10½
Medicine Hat	369	29	12
MacLeod	301	26	11
Lethbridge	334	26	11
Swift Current	517	36	15
Moose Jaw	628	35	14
Coronation	205	21	9
Kerrobert	322	24	10½
Hardisty	137	18	7½
Saskatoon	368	29	11
Brandon	735	47	18½
Winnipeg	848	50	19½

[1] The above schedule has been furnished (April, 1925) by the District Freight Agent, C.P.R., Edmonton.

On the above basis if shipped under the sand-gravel classification, the rate on bituminous sand from points near McMurray to Edmonton, (approximate distance 300 miles), would be approximately 11 cents per 100 pounds.

In the past, consideration of the merits of bituminous sand has been based largely on the assumption that mixes in which it may be incorporated must conform to present recognized standard paving specifications. In the opinion of the writer, an attempt should be made rather to design a mix in which the admittedly valuable inherent merits of the material will be utilized to the greatest advantage. At present it is not definitely known whether a large tonnage of uniformly graded bituminous sand is available, but in the writer's opinion, areas may be found where such sand exists.

It appears that the problem involved in the suggested use of crude bituminous sand for paving purposes is economic rather than technical since apparatus for the heating and mixing the necessary raw materials has been available for some years. In the United States large markets are available and operations can be conducted on a sufficiently large scale to warrant the use of efficient mechanical equipment, and to justify the granting of low freight rates. In western Canada the present market is limited.

V. STUDY OF RECOVERY OF HYDROCARBONS FROM BITUMINOUS SAND AT MELLON INSTITUTE OF INDUSTRIAL RESEARCH, PITTSBURGH, PA.

It is obvious that proposed commercial development of the bituminous sand in the McMurray area must take into consideration the following general factors:—

(1) assurance that ample supplies of suitable raw material are available;

(2) that mining and other plant equipment can be secured and installed at reasonable cost;

(3) that labour is available at reasonable rates and can be retained under local conditions;

(4) that products can be disposed of (and competition successfully met) at remunerative prices and without involving undue storage charges owing to seasonal demand.

Indeed it appears that, in the past, the importance of first cost of storage equipment as well as storage charges, has been underestimated. Material reduction of such costs would be effected by converting crude petroleum into finished products. Reduction in weight and bulk of such products would also be reflected in reduced freight costs, investment in expensive tank-car equipment, and in extended radius of distribution. Development of bituminous sand at points somewhat removed from present rail transportation would introduce the problem of additional transportation by water, pipe line or railroad, and only large and assured production would warrant the necessary capital expenditure to provide such facilities. Consequently

for the immediate present, effort should be directed toward determining the true value of those areas which are adjacent to existing rail transportation, or its proposed extension to McMurray settlement.

The writer considers that the McMurray deposit should be regarded primarily as a possible source of liquid hydrocarbons. It should also be regarded as an important potential source of solid and semi-solid bitumen, and of crude bituminous sand, adapted for various types of wearing surfaces and the preparation of asphalt mastic. It appears probable that the production of bituminous sand for use in a more or less crude form and of separated bitumen will precede production of liquid hydrocarbons.

The writer's laboratory study of methods adapted to the recovery of hydrocarbons from bituminous sand has of necessity been very limited, and was discontinued early in 1917. Results of subsequent investigations by private individuals and others have, to a large extent, superseded the above work, and, consequently, only a very brief reference thereto is necessary.

At present it is somewhat difficult to indicate, even approximately, the distances to which, under favourable conditions, crude bituminous sand may ultimately be shipped for paving and other similar purposes. However, since 1913, the writer has insisted on the desirability of developing a successful commercial process whereby wholly or partly purified hydrocarbons might be recovered. The maximum degree of purity, consistent with cost, should be aimed at, but it must be recognized that, in attempting to secure a product 100 per cent pure, the cost curve may be expected to rise much more rapidly during final stages of purification.

After due consideration, it appeared desirable to undertake the investigation of a possible separation process at the laboratories of the Mellon Institute of Industrial Research at Pittsburgh, Pa., and accordingly, on May 1, 1916, the writer was appointed an Industrial Fellow at that institution. It is important to note that the bituminous sand used at the Mellon Institute consisted of material which had been excavated from natural exposures 18 months previously. The writer has always maintained that separation can be effected with much greater efficiency and at much lower temperatures with freshly mined material secured at points somewhat removed from weathered outcrops. This feature must be kept in mind in considering determinations of specific gravity, viscosity, efficient temperatures, etc., noted in the following pages. In this connexion it is of interest to note, as an analogy, that the effect of oxidation on the extractive material and on the coking properties of certain coals at low temperatures, has long been recognized. This feature is discussed in the writings of Parr,[1] Hadley and others on the extraction of coal with various solvents. "The further effect of oxidation was noticed in a number of ways. For example, the amount of material that could be extracted from coal, depended to a certain degree on the extent of oxidation . . . . . Oxidation decreases the amount of material which may be extracted from coal by phenol, and the coking properties are decreased in proportion to the extent of oxidation."

At the outset it is necessary to assume certain possible commercial applications for the partly or wholly refined products derived from the bituminous sand. Among these may be mentioned, asphalt cement to be

[1] University of Illinois, Bulletins No. 60 and No. 76.

used as a binder in connexion with paving construction; in the preparation of synthetic asphalt mastic; in the briquetting of certain fuels; and as an ingredient in the manufacture of paints, varnishes, roofing materials and similar products.

At the outset three important considerations were recognized.

1. There was little technical literature dealing with separation of bitumen from bituminous sand or sand rock. The data consisted of incomplete information, personally secured, regarding separation processes that have been attempted between 1890 and 1913 in various parts of the United States. With possibly one exception, none of these attempts had met with commercial success—a result due largely to the use of inapplicable principles and imperfect mechanical devices. To a lesser extent, legitimate competition with other bituminous products also militated against successful operation of separation plants.

2. Recognized purification methods, usually regarded as standard practice, are not applicable in the treatment of bituminous sands. A notable exception was suggested in the case of hydraulic classifiers. No systematic data were available regarding the settling action—free or hindered—of a sand-bitumen-hot water mixture.

3. Neither accurate, nor systematic data were available regarding actual results that might reasonably be expected from separation, either by the use of solvents or of heated water. Obviously low-grade ores, or other low-grade material, such as bituminous sand, call for methods of preparation which combine low cost and efficiency.

RECOVERY OF HYDROCARBONS

Recovery of hydrocarbons may be considered under:—

1. Separation of bitumen unchanged by,—
   (A) Use of solvents.
   (B) Use of heated water, with or without the addition of reagents.

2. Recovery of bitumen in the form of crude petroleum, (or already converted into its finished products), by distillation.

1. Use of Chemical Compounds and of Petroleum Distillates as Solvents

(a) Separation of Bitumen Depending on Use of Chemical Solvents. Only two chemical compounds need be considered as solvents, namely, carbon bisulphide and carbon tetrachloride. A summarized statement concerning these is as follows:—

Name	Sp. Gr. 25° C.	Boiling-point	Cost per pound f.o.b. factory car lots 1924	Equivalent cost per gallon	Relative separation efficiencies at 30° C.
			cts.	$ cts.	
Carbon bisulphide (C.P.)........	1·28	49 °C.	5½	0 70	4
Carbon tetrachloride (C.P.)......	1·63	78° C.	7	1 14	3

Solutions of gums, resins, natural pitches, asphalt, etc., have been reported, but results have either received only partial confirmation or are of a conflicting nature. Carbon tetrachloride has been used in connexion with the separation of fats, oils, waxes, asphalts, resins, dyes, and alkaloids; but in the published accounts of these applications, no mention is made of quantitative data.

Determination of the solvent properties of carbon tetrachloride at 30° C. was therefore attempted. The solvent, with an excess of bitumen, was placed in a glass-stoppered bottle, and occasionally agitated until a saturated solution was obtained, after which 20 c.c. of the solution was drawn off and weighed. The solvent was then evaporated at 60 to 70° C., and the residue weighed. Various determinations were made but with no concordant results. This was apparently due to the soft nature of the bitumen under consideration, and also to the fact that the tetrachloride and the bitumen are soluble in each other and miscible in all proportions.

Regarding the solvent properties of carbon bisulphide, fewer data are available than in the case of carbon tetrachloride. This is undoubtedly due to the non-inflammable nature of carbon tetrachloride. In the determinations attempted, the method adopted was the same as in the case of carbon tetrachloride. No concordant results could be obtained.

(b) Separation Depending on Use of Petroleum Distillates. Samples of the following petroleum distillates commercially available were secured, and a determination of their relative values as solvents attempted,—(1) gasoline (62° Bé.); (2) naphtha (49·3° Bé.); (3) straight tops (52·4° Bé.); (4) No. 1 engine distillate (48·1° Bé.); (5) kerosene (41·2° Bé.); (6) gas oil (23·8° Bé.).

Various methods were resorted to in an attempt to determine the relative solvent efficiencies of the above distillates, during various periods of time, degrees of temperature, and degrees of agitation. Data such as would definitely establish the relative efficiencies could not, however, be secured with apparatus available. Indeed the soft bitumen under consideration appeared to be almost equally miscible in each of the distillates used.

From the above it appears that, with suitable apparatus, either carbon tetrachloride or carbon bisulphide would answer the purpose of a solvent on a commercial scale. The bitumen associated with Alberta bituminous sand, is completely soluble in both of these compounds, but no figures on its exact solubility can be determined by present methods.

Of the two, carbon tetrachloride is preferable because of its non-inflammability, uniformity of composition, low freezing-point (—24·7° C.) and higher boiling-point. Carbon bisulphide is much more volatile, and although danger due to its use, may be greatly reduced through the perfecting of apparatus, yet constant care by responsible employees will not entirely eliminate the risk to life and property.

As compared with certain petroleum distillates, the advantages possessed by carbon tetrachloride, are not sufficient to outweigh its higher cost, for in separation processes depending on volatile solvents, the volume of the solvent and not its weight is to be considered. It is clear that for equal volumes of solvent, more than twice as much carbon tetrachloride

by weight must be used, as, for example, tops. Carbon tetrachloride also attacks iron and copper and hence lead or tin-lined apparatus must be used. Moreover, the difference in favour of carbon tetrachloride in cooling water required for condensing the vapours, is too small, even though lower insurance premiums be considered, to counterbalance the difference in cost of quantities used.

Thus, in discussing the commercial separation of bitumen, it appears that carbon tetrachloride and carbon bisulphide cannot be seriously considered. In 1924, these solvents sold at 7 and 5½ cents per pound, respectively, f.o.b. factory.[1] Moreover, it is altogether improbable that they will be able to compete with benzine or other similar solvents,—such as certain petroleum distillates derived directly without involving so many chemical products. The investment in electrolytic cells to produce chlorine in a carbon bisulphide plant and in a carbon tetrachloride plant is so very great, that it is doubtful if there is much possibility of reducing materially present costs of these solvents.

The writer considers that the choice of solvent should not be based on fine distinctions regarding apparent relative solvent efficiency, as indicated by results of laboratory determinations, since apart from rapidity of separation such determinations cannot be considered as conclusive. It may however be assumed that any attempted commercial use of solvents in connexion with the separation of bitumen from bituminous sand will imply the adoption of a petroleum distillate. Moreover, it appears to be the result of general experience that the lighter the distillate used, the less soluble are the harder bitumens.

First cost, accessibility of an assured supply of solvent, and subsequent recovery with minimum loss,[2] are considerations of primary importance. Among the distillates referred to above, this would restrict a selection to Nos. 3, 4, and 5.

Tops are valued on the basis of their gasoline content. They will undoubtedly become more valuable as the gasoline situation becomes more acute. The gravity of straight tops, similar to No. 3, usually varies from 50° to 53° Bé., and in some instances as high as 56° Bé. The lighter grades will probably contain some casing-head gas mixed with it, and this will decrease its adaptability as a solvent. Engine distillate and kerosene will also increase in importance in the future in proportion to their adaptability as motor fuels. This will leave as the only cheap solvents available those distillates which come after kerosene and before lubricating oil possibility with a gravity of about 45° Bé. Such distillates would have a relatively high boiling-point, and their use would imply an unduly large expenditure of heat in redistillation recovery.

In conclusion it may be stated that separation of bitumen from bituminous sand by use of the solvents referred to above, is quite practicable, if considered merely as a problem in treatment and manipulation. Commercial adaptability would depend on first cost of solvent, loss of solvent, and cost of recovery of solvent from sand tailings, and from the dissolved bitumen itself.

[1] Dow Chemical Company, Midland, Mich., U.S.

[2] Losses of solvent will be due to
(a) unavoidable leakage;
(b) evaporation;
(c) becoming enmeshed in voids in sand tailings.

2. Preliminary Separation of Bitumen by Use of Heated Water

Owing to the loose nature of the crude bituminous sand, the voids are not entirely filled with bitumen and moisture. Consequently, some air is also present throughout the mass. In proof of this it may be stated that fragments of 15 per cent fine-grained bituminous sand have a specific gravity of approximately 1·75. The same material, when compacted under a pressure of 15 tons per square inch, has a specific gravity of approximately 2·02.

From the writer's personal experience in quarrying bituminous sand, it is probable that deliveries of material from the quarry will contain many pieces up to 100 pounds in weight.[1] To attempt to sledge such masses would involve greater expense than the actual quarrying itself. Moreover, at times, the crude material carries small lumps of pyrite ranging up to 3 pounds in weight, which with other impurities might prove a source of trouble at some stage of the treatment. Consequently it is desirable that as a preliminary step, some form of rough crushing be resorted to—such as steam-heated, toothed rolls. From these rolls, the crushed material could be passed over some type of steam-heated grizzly, thus furnishing oversize and material for the charging-floor.

Fragments of crude bituminous sand placed in hot or cold water immediately gather small air bubbles on their surfaces, the number of these bubbles increasing with increase in temperature of the water. These bubbles act as small balloons and tend to hold the fragments of bituminous sand in suspension. With the disintegration of the fragments into individual grains, the air bubbles largely disappear under the action of heat. They may be replaced to some extent by small oil-gas bubbles.

The more complete the disintegration of the sand aggregate the more efficient will be the action of the heated water. The temperature employed must be high enough to melt the bitumen, and so reduce its viscosity that the naturally greater surface tension of the water will be otherwise unopposed, and free to overcome the lesser tension of the fluid bitumen.

From this it will be seen that an efficient and thorough preliminary disintegration of the crude bituminous sand is essential to any separation process. To some extent this will be effected by the action of the hot water, but, in addition, some form of mechanical disintegration is also desirable, if not absolutely necessary.

The problem of mechanical disintegration was, therefore, discussed personally with representatives of the Paul O. Abbe Company of New York; Charles Ross & Son of Brooklyn; J. H. Day Company of Cincinnati, Ohio, and the Seers Manufacturing Company of Buffalo, N.Y. As a result, it appears that some type of bar disintegrator, arranged with specially designed arms, will give the most satisfactory results. An actual trial of such a disintegrator has not yet been made.

[1] The use of certain types of excavating equipment referred to in Chapter IV would largely overcome this difficulty.

3. Determination of Physical Constants

In considering separation of bitumen from Alberta bituminous sand, the following preliminary determinations were attempted.

(a) *Specific gravity of bitumen associated with Alberta bituminous sand at various temperatures.* Bitumen separated from the bituminous sand, by the writer, has a specific gravity ranging from 1·018 to 1·04 at a temperature of 77°F. It is probable that samples taken from different points throughout the McMurray area, will show some variation. This bitumen will obviously sink in water at temperatures approximately 77° F., and it is possible that, in final dehydration of the bitumen, settling may appear desirable. Initial separation of bitumen from bituminous sand, by the use of heated water, will require sufficient heat to allow of a clean separation through differences of specific gravity of water and of bitumen.

The specific gravity of bitumen was determined at temperatures up to 406° F., by weighing a copper rod in heated bitumen. The following results were obtained.

Temperature	Specific gravity	Temperature	Specific gravity
405° F.	0·821	320° F.	0·873
400° F.	0·826	300° F.	0·878
390° F.	0·829	280° F.	0·889
380° F.	0·841	250° F.	0·907
360° F.	0·845	77° F.	1·040
350° F.	0·858		

(b) *Temperature viscosity relations.*

(1) Separated bitumen.

(2) Crude bituminous sand.

(1) Viscosity determinations of separated bitumen were made by means of a Scott viscosimeter. The use of Engler and of Saybolt viscosimeters was also attempted, but results were unsatisfactory. In making determinations 50 c.c. of bitumen was used, with the following results:—

Temperature	Time in Secs.	Temperature	Time in Secs.
400° F.	19·5	250° F.	239·5
360° F.	20·3	200° F.	288·1
300° F.	47·7		

(2) Viscosity determinations of crude bituminous sand were undertaken by Mr. Alex. L. Field of the United States Bureau of Mines, through the courtesy of Dr. Van H. Manning, Director. The results of this work were inconclusive.

Considering results of viscosity determinations in conjunction with results of specific gravity determinations, it appears that the temperature at which most efficient results can be attained in the separation of the bitumen, is not less than 250° F. and need not exceed 360° F.

In considering separation by means of heated water, it appears that a preliminary sizing of the bitumen-coated grains would prove advantageous. Experiments with a tubular classifier, in which water was heated to various temperatures up to 200° F., indicated the rate of fall of grains of varying diameter. Against the rising current the coarser, heavier grains

fall much more rapidly than the finest grains, which almost invariably become enmeshed with the bitumen that gathers on the surface of the water.

A number of outline plans were prepared, showing various possible arrangements of a classification process. These were submitted to certain makers[1] of ore-milling machinery and the following conclusions arrived at:

(*a*) The bituminous sand is too sticky to permit of even a rough classification. Even if it were possible to completely disintegrate the crude sand as a preliminary step, the individual grains would almost at once re-form into groups.

(*b*) Classification would not be mechanically practicable in closed apparatus operating under pressure. The use of water at 212° F. in open apparatus would imply low separation efficiency and excessive heat losses.

During the period 1892-1911, a number of attempts were made in the United States and elsewhere, to separate bitumen from bituminous sand by the use of heated water. Open apparatus were used, with water at temperatures approximately 212° F. Under such conditions the product contained varying percentages of mineral matter and of water.

In 1916, Messrs. C. L. Cook and J. R. Price suggested the use of water heated under pressure to temperatures higher than 212° F., and constructed at Oakland, Cal., a small experimental unit. With the apparatus available it was difficult to determine ideal working temperatures, although preliminary results were encouraging. Accordingly, the writer constructed a heating cylinder, 5 feet high and 12 inches in diameter, designed to withstand a pressure of 250 pounds. This cylinder was equipped with feeding and discharging devices. Glass ports were also provided to permit observation of progress of separation at various temperatures.

SUMMARIZED RESULTS OF SEPARATION

As a result of a series of trial runs, it became evident that radical modifications in the dimensions and construction of the cylinder would be necessary in order to secure satisfactory results. In the time available, it was not possible to make these necessary changes. However, with the cylinder as constructed it was possible to determine the temperatures at which separation was best effected. Consequently four trial runs were made, the charge of bituminous sand in each case being approximately 1·5 pound. The results of these runs were summarized as follows:—

Number	Period of heating	Average maximum temperature	Corresponding pressure	Purity of product
			lb. per sq. in.	per cent
1	30 mins.	250° F.	30	63
2	30 "	275° F.	45	68
3	30 "	300° F.	67	79
4	30 "	325° F.	96	88

[1] Allis Chalmers Manufacturing Co.
Colorado Iron Works.
Deister Machine Co.
General Engineering Co. (Salt Lake City).

During the progress of the above and other preliminary runs, it was possible to make careful observation of conditions inside the separation cylinder, from which the following conclusions were deduced:—

(*a*) There are usually chemical and physical differences in bitumens derived from bituminous sands from different areas. These differences will in each case require a modification in the temperature of water used. It has been found that at a temperature of 315° to 325° F., separation of bitumen from Alberta bituminous sand may be effected efficiently. A lower temperature (300° F.) will achieve the same result but the action will be slower. At temperatures lower than 300° F., considerable fine sand and silt remain enmeshed with the bitumen.

(*b*) When using a small experimental cylinder best results are secured when heat is applied at the bottom of the tank. If heated in this way no artificial agitation is necessary as the ebullition of the water is sufficient.

(*c*) The column of water must be of sufficient depth to permit of settling out of sand particles. This does not necessarily imply an excessive depth.

(*d*) A device should be arranged to remove the separated bitumen as it reaches the surface of water. This can be accomplished more readily in an apparatus of horizontal construction.

(*e*) Drawing off under steam pressure results in hardening the bitumen.

(*f*) Exposure of bituminous sand to high temperature prior to separation, should not be for a longer period than is absolutely necessary owing to resulting hardening.

(*g*) At temperatures lower than 300° F., considerable sand remains mixed with the bitumen. On the other hand, even when strong agitation is resorted to, the tendency of the sand to remain enmeshed with the bitumen is much less when a temperature sufficiently high is maintained. The purity of the product thus depends largely on the temperature employed.

(*h*) A period of complete rest prior to drawing off the bitumen is desirable.

(*i*) Separation of bitumen should commence from the time the crude bituminous sand enters the charging apparatus. The addition of a small percentage of petroleum distillate at this stage will accelerate subsequent separation. This could be effected by feeding through intermediate steam-heated tanks.

(*j*) In designing apparatus, every care should be taken to prevent lodgment of material undergoing treatment. At various separation plants in Oklahoma and California, owing to poor designing, costs of cleaning separation tanks were almost prohibitive.

(*k*) The rapidity of separation will be affected to a marked degree if the bituminous sand is exposed to atmospheric influences for any considerable period after it has been excavated.

(*l*) Information available indicated that heating by steam jackets has advantages over live steam introduced into the water.

(*m*) The addition of reagents to the water should be carefully considered. It has been noted above that the addition of small percentages of various acids, notably sulphuric, accelerates separation. In 1913 Mr.

A. D. St. John, of the Municipal Testing Laboratory, New York, and more recently (1917) K. A. Clark and R. T. Elworthy of the Mines Branch, have suggested the addition of an emulsifying agent to the water. The addition of sodium hydroxide has also been suggested (1917) by E. A. Thompson of the Mines Branch.

A series of preliminary tests on a small scale, appears to justify the above suggestion. Thus, when 5 c.c. of saturated sodium hydroxide solution is added to 300 c.c. of water, and the bituminous sand heated with this solution to 75° to 90°C., bitumen separates, giving a product approximately 50 per cent pure. The residual sand tailings are also much cleaner than when water only is used. An exhaustive series of experiments, using various reagents, appears desirable.

(*n*) The admixture of a small percentage of petroleum distillate with the crude bituminous sand prior to hot water treatment appears to accelerate separation. No systematized data are available regarding this.

4. Final Purification

As already noted, in making use of heated water as a separation medium, the maximum degree of purity in the separated bitumen, consistent with cost, should be aimed at. It must, however, be recognized that in attempting to secure a product 100 per cent pure, the cost curve may be expected to rise much more rapidly during the final stages of refining.

After due consideration, it appears that only an actual demonstration on a semi-commercial scale can definitely establish the commercial possibilities of any process or method for separating bitumen from bituminous sand. Meanwhile, results of laboratory work have indicated that, in the hot water treatment of a moderately fine-grained bituminous sand, a bitumen 85 per cent pure may be obtained.

It is possible that further hot water treatment would have resulted in a greater degree of purity. It was, however, considered that further refining could be secured more efficiently by—

(*a*) Use of settling-tanks heated (by means of jacketing) to 150° to 175°F.,

(*b*) Use of centrifuges,

(*c*) Use of filters.

As it was difficult to secure a sufficiently large sample of bitumen from the crude bituminous sand, a synthetic mixture was prepared by combining petroleum residuum, flux, and definite quantities of fine, graded sand. The resulting mixture corresponded in penetration and viscosity to the product derived from the preliminary hot water separation. This synthetic mixture contained approximately 14 per cent aggregate and was sealed for shipment in 5-gallon containers. Even while stored in the containers, a considerable settling out of the aggregate took place.

(*a*) *Use of Heated Settling-tanks.* From information available regarding use of heated settling-tanks at various separation plants in Oklahoma and in California, it appears that the use of such tanks has given satisfactory results.

(*b*) *Use of Centrifuges.* The use of centrifuges in connexion with the refining of bitumen is not new, although no technical literature dealing with this subject is available. The first attempts of this nature with which the writer is familiar were made by the Alcatraz Asphalt Company at Carpinteria prior to 1900, under the supervision of Mr. A. F. L. Bell. Mr. Bell states that the experimental work at that time was not conclusive, but gave encouraging results. Since then the commercial application of centrifugal apparatus has been greatly extended and a high degree of mechanical perfection has been attained. Centrifuges are now commonly constructed, having a basket diameter of 12 to 60 inches, and a maximum load capacity of 1,500 pounds. Few machines are, however, constructed with a greater diameter than 60 inches, the size generally used having a 40-inch basket with a load capacity of 400 to 800 pounds per charge.

It should be remembered in the case of large centrifuges, that, as the size of the basket increases, the centrifugal effect becomes less for a given peripheral speed, due to the lesser curvature. Owing to the greater load and increased circumference, the mechanical stress increases with any increase in the size of basket, so that a limit to the size is soon reached. The most efficient size will vary with the material, being larger for coarse material which is easily cleaned, and decreasing as greater centrifugal effect is required. As the centrifugal force in a centrifuge is several times the weight of the material, considerable energy is required to remove the material. Also, if the material is discharged at a high velocity, the velocity of the discharged material represents a considerable amount of lost energy which must be supplied to the machine.

In order to secure reasonable efficiency, continuous feed, and discharge of separated product and of waste sands would be essential. As yet the centrifuge has not been adapted to continuous operation. Other objections to this type of apparatus are: multiplicity of units necessary in handling large throughput, large number of skilled attendants, and danger from accidents.

Nevertheless, assuming that bitumen 85 per cent pure can be successfully separated on a commercial scale from the Alberta bituminous sand, the question of removing the final 15 per cent of foreign matter bcomes of interest. Consequently the commercial applicability of the centrifuge principle in connexion with partly refined Alberta bitumen, has been discussed with the American Laundry Company, Cincinnati, Ohio; Tolhurst Machine Company, Troy, N.Y.; and the Fletcher Works, Philadelphia, Pa. The representatives of these companies with whom the matter was taken up, are familiar with the best present day centrifuging practice.

The Tolhurst Machine Company and the American Laundry Company each offered the loan of one or more centrifuge machines, and promised their co-operation in any experimental work that might be undertaken. To secure conclusive results, however, would have required at least three months' time, and considerable expense.

Finally, the question was taken up in detail with Mr. Leslie Griscom, engineer in charge of the testing laboratory of the Fletcher Works.[1] As a result, Mr. Griscom agreed to conduct a series of experimental tests.

[1] The Fletcher Works, Glenwood Avenue and Second Street, Philadelphia, Pa.

A shipment of the prepared mixture was forwarded to the laboratory of the Fletcher Works, and the following report received:—

Enclosed please find a copy of the report of our engineer on the sample of bitumen you sent us.

The readiness with which the bulk of the sand can be precipitated is rather striking.

On account of the large amount of sand to be handled, a special design of machine would be desirable if the industry is to reach extensive proportions.

Awaiting your further advices after you have perused the enclosed report, we remain,

Very truly,
FLETCHER WORKS,
(Signed) A. SCHROEDER,
Manager.

RESULT OF TEST ON BITUMEN FROM MELLON INSTITUTE

The sample of bitumen as received contained about 10 per cent sand. The object of the test was to separate the sand from the bitumen. At room temperature, the bitumen is in a plastic condition, and had to be heated to 300° F. to liquify it. Three tests were made. In each test a sample was centrifuged for one minute, two, and three minutes. Then a portion of each sample was weighed in a beaker and the bitumen dissolved in benzine, leaving the sand behind. In this way, the per cent of sand left in the bitumen after centrifuging was found.

The results of the test are as follows:—

Run No. 1—

Per cent of sand in sample as received..	9·13
On centrifuging 1 minute, per cent of sand left..	0·32
" " 2 minutes, " " "	0·26
" " 3 " " " "	none

Run No. 2—

Per cent of sand in sample as received..	17·2
On centrifuging 2 minutes, per cent of sand left..	0·71
" " 3 " " " "	0·4

Run No. 3—

Per cent of sand in sample as received..	9·43
On centrifuging 1 minute, per cent of sand left..	0·45
" " 2 minutes, " " "	0·309
" " 3 " " " "	0·271
" " 5 " " " "	0·234

The average of these runs was:

Per cent of sand in sample as received..	11·92
" " " left after centrifuging 1 minute..	0·38
" " " " " " 2 "	0·246
" " " " " " 3 "	0·223

The average temperature range for these runs was:

For centrifuging 1 minute, 290° F. to 200° F.
" " 2 minutes, 290° F. to 180° F.
" " 3 " 290° F. to 150° F.

A machine to handle bitumen must be kept at a heat of not less than 300° F. as bitumen becomes plastic rapidly at lower temperatures.

It may be added that a series of experimental runs has demonstrated that centrifugal apparatus will not separate bitumen from 15 per cent crude bituminous sand at temperatures below 280° F.

The cost of separating the bulk of the sand from a mixture containing 85 to 90 per cent sand will depend upon so many unknown factors, that any present approximation might easily prove misleading.

To secure data applicable to results that may be expected from different sizes of commercial machines it would be necessary to repeat the tests referred to above, with the centrifuge running at different speeds. A suggested method of operation would be somewhat as follows:—

The semi-liquid bitumen-sand mixture would be fed into the centrifuge while running at speed. The sand would be deposited in the basket, and the freed bitumen allowed to overflow or to be collected by means of an offtake tube, projecting into the revolving mass. As the basket becomes filled with sand the bulk of the bitumen remaining in the basket is correspondingly reduced, and consequently the effective capacity of machine. For example, if we have a bowl with a wall capacity of 12 cubic feet, and if it requires 3 minutes to precipitate the sand associated with the bitumen-sand mixture, then the initial capacity of the centrifuge would be 4 cubic feet per minute. When the deposited sand has increased so that it occupies a volume of 6 cubic feet, the capacity would be reduced to 50 per cent or 2 cubic feet per minute. If such a machine were stopped when the basket had become half filled with sand, the capacity, while running, would probably approximate 3 cubic feet of bitumen before stoppage to remove the sand became necessary.

An average capacity rate of 3 cubic feet per minute, would mean that the machine would be running $13\frac{1}{2}$ minutes on a single charge. If we assumed 2 minutes for starting, $1\frac{2}{3}$ minutes for stopping, and 3 minutes to unload, we would thus have a cycle of 20 minutes, or 3 charges per hour, equivalent to 120 cubic feet of bitumen. The cycle would also have to include the time necessary to fill the basket, and to skim the bitumen remaining in the basket after feeding is stopped. Whether such a cycle could be maintained in practice would depend on the facilities for removing the sand, as well as on other features. Owing to frequent starting and stopping, one operator would probably be required for each machine.

Assuming power and labour costs, some general idea of refining cost can be deducted from the above. While it appears that centrifugal methods are not adapted to preliminary treatment of the bituminous sand, the development of centrifuges[1] in purifying crude petroleum, indicates that they may possibly be found applicable to final treatment of partly purified bitumen. For separating water, but not silt, heated centrifuges now in use have a capacity of 6 to 16 barrels crude petroleum per hour, depending on the character of the emulsion. It is thought that separation of water from heated bitumen by centrifuging may possess sufficient possibilities to warrant a certain amount of experimental work. Shaking screens, commonly known as "shakers", and formerly used in connexion with the Vienna yeast process, might also be adapted to the removal of silt.

[1] The De Laval Method of Purifying Petroleum Oils, No. 104.

(c) Use of Filters in Final Stages of Purifying Bitumen. In attempting the filtration of partly refined bitumen, apparatus manufactured by the following firms was considered:—

T. Shriver and Company, Harrison, N.J.; Kelly Filter Press Co., Salt Lake City, Utah; Sweetland Filter Press Co., Brooklyn; Industrial Filtration Co., New York.

After observing types of machines manufactured by each of these companies in operation, it was decided to submit 5-gallon samples of partly refined bitumen to the Sweetland Filter Press Company, and the Industrial Filtration Company. As it was practically impossible to separate such large samples from the bituminous sand, a combination of oil asphalt and flux was prepared, corresponding in gravity and in viscosity with the Alberta material. With this were thoroughly mixed definite percentages of graded sand. The two samples prepared in this manner were then passed through the filters, with the following results:—

I. Sweetland Filter Press Company, Brooklyn.

Analysis of original sample:

Bitumen, 94 per cent; sand (100/200), 3 per cent; and sand (200/—), 3 per cent.

Analysis of filtrate secured:

Bitumen, 99·77 per cent; sand (grading not determined), 0·23 per cent.

Temperature 255° F.; vacuum—24 inches; type of filter—leaf; filtering medium—200-mesh wire and canvas.

II. Industrial Filtration Company, New York.

Analysis of original sample:

Bitumen, 91 per cent; sand (100/200), 5 per cent; and sand (200/—), 4 per cent.

Analysis of filtrate secured:

Bitumen, 99·60 per cent; sand (grading not determined), 0·40 per cent.

Temperature—275° F.; vacuum—27 inches; type of filter—leaf; filtering medium—200-mesh wire.

Costs of filtration by either of the above types of filter cannot be stated definitely. It was, however, considered (1916) by those familiar with various types of filters, that the cost of filtering 85 per cent sludge would probably not exceed $1 per ton of refined product.

Cataphoresis. The possible application of cataphoresis, in removing a part at least of the finer material associated with the partially refined bitumen, was also considered. It was found, however, that owing to the coarseness of sand particles, the bulk of the sand would be entirely unaffected by the usual surface tension phenomena, and hence also by electro-osmosis.

DEHYDRATION[1]

It may be assumed that bitumen derived from bituminous sand by means of a hot water separation, will have associated with it a considerable percentage of water. Six methods of dehydration may be mentioned.

1. *Milliff system.* Heated air is blown through the mixture by means of perforated pipes. Such a method will harden the bitumen owing to oxygenation.

2. *Indirect heat.*

3. *Direct heat.* Both of these methods would probably cause frothing.

4. *Munster method.* The heated bitumen and water is sprayed against a rotating wheel or surface heated above 212° F. and the water, being in the form of a fine spray, is reduced to steam. This is very effective in breaking up emulsions. It is usually preceded by allowing the material to be treated and settle out in a heated settling-tank. It has defects similar to the Milliff system, but to a lesser degree.

5. *Gravity in heated settling-tanks.*

6. *Centrifuging.*

None of the investigations referred to in preceding pages were carried beyond the laboratory stage, and it is difficult to deduce final conclusions. If, however, certain of the principles which have been applied on a laboratory scale, are accepted, the separation problem becomes largely mechanical. A number of designs of suggested apparatus were, therefore, prepared. Two-stage operation and continuous operation, versus interrupted or intermittent operation, were considered.

Assuming either continuous or intermittent operation, three general types of construction were outlined:—

(*a*) Vertical construction, depending on retarded fall of bituminous sand through a considerable depth of water.

(*b*) Horizontal construction, with a revolving screen or trommel, fitted with a specially designed system of lifters to ensure disintegration and propulsion.

(*c*) A combination of vertical and horizontal construction.

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[1] American Petroleum Industry, Bacon and Hamor.
Journal of Gas Lighting and Water Supply, vol. 132, pp. 261 and 375.
German Patent 231222, March 23, 1910.
Austrian Patent 2229-11, March 14, 1911.
U.S. Patent 1070555, August 19, 1913.
German Patent 248872, March 25, 1910.
German Patent 244064, January 20, 1911.
Beazley, Oil Age, 1911, 21; a; sp. Petrol.
Rev. 26,284; Trans. Am. Inst. Min. Eng., 43,514, and Western Eng., April, 1912, Petrol. Rev. 26,284.
U.S. Patent 1116299, Nov. 3, 1914.
U.S. Patent 1142759-60-61; June 8, 1915.
Bull. Am. Inst. Min. Eng., 1915, No. 99,637.
On the Dehydration of California Petroleum; see also Beazley, Western Eng., 1 (1912), 56.
Paine and Stroud's "Oil Production Method," 1913, 163.
Tar Dehydration. E. V. Chambers, (Paper read before the Manchester District Institution of Gas Engineers)
Abraham, Herbert, Asphalt and Allied Substances.
U.S. Pat. 512494 (1894) to R. D. Upham.
Journ. Soc. Chem. Ind., vol. 33, 1914.
Am. Gas Light Jour., vol. 102, 1915.
Electrical dehydration of tars; U.S. Pats. 1116299 (1914); 1142759, 1142760, 1142761 (1915).
Hardison, Trans. Am. Inst. Min. Eng., vol. 99, 1915.

Features common to each of the above types of construction were charging and discharging devices, agitation zone, quiet water or separation zone, and provision for removal of separated bitumen.

In February, 1917, the use of flotation methods was suggested. In the limited time then available, it was not possible to secure suitable apparatus, but a number of preliminary tests were made with a small flotation cell designed for the concentration of sulphide ores. In making these tests, small percentages of various reagents, both acid and alkali, were added to the water.

Under the circumstances, results obtained were inconclusive. Moreover, subsequent comprehensive research along somewhat similar lines,[1] has so progressed, as to entirely supersede the writer's work at the Mellon Institute.

5. Recovery of Bitumen as Liquid Hydrocarbons by Distillation[2]

General Considerations

Since 1914, the writer has maintained that the McMurray deposit of bituminous sand should be regarded as a potential source of liquid hydrocarbons. Subsequent observation has confirmed this opinion. Technically and economically, such production constitutes a many-sided problem which can merely be touched upon in a general report, and in certain respects is analogous to that presented by the proposed development of petroliferous shales. It is true that average content of crude petroleum per ton of bituminous sand is less than that of many of the shales of New Brunswick, Nova Scotia, and certain fields in the United States[3], and that the amount of nitrogen that might be recovered in the form of ammonium sulphate would be negligible. On the other hand, in a majority of instances, the cost of mining bituminous sand[4] would certainly be much lower than in the case of oil-shales.[5]

Production of petroleum from Alberta bituminous sand will constitute a problem which is, in many respects, similar to the mining and treatment of low-grade ores. Satisfactory financial returns will depend on large throughput capacity together with able technical, business, and administrative control. Production will be directly affected by the future trend of the petroleum situation in the United States and by development of other foreign fields, the potential importance of which is, in many instances, as yet unknown. Other factors to be considered include possible competition with certain suggested substitutes for petroleum, labour supply, transportation, and developing and holding stable and assured markets.

The importance of production of liquid hydrocarbons from bituminous sand, if commercially feasible, requires no emphasis. Petroleum has become

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[1] Notably by J. M. McClave, Western Research Corporation, Denver, Colo.

[2] Total quantities and value of petroleum products other than solid and semi-solid asphalts entered for consumption in the provinces of Manitoba, Saskatchewan, Alberta, and British Columbia.

1921-22		1922-23	
Gals.	Value	Gals.	Value
168,057,671	$13,111,167	167,705,479	$11,998,088

[3] Gavin, M. J.: Oil Shale: an Historical, Technical and Economic Study. Bull. 210. U.S. Bureau of Mines; see also Colorado School of Mines Quarterlies.

[4] See Chapter IV.

[5] As yet no oil-shales of commercial value have been found in western Canada. See "Oil Shales of Canada," S. C. Ells. Mines Branch Report No. 588.

a fundamental necessity in the military and industrial life of a nation. Fuel oil is necessary for a navy, a mercantile marine,[1] and for large industrial plants. Lubricating oil is essential for all machinery.

At present Canada depends largely on the United States for her supplies of petroleum products. Yet in the United States, with a production of crude petroleum during 1923 of 725,702,000 barrels,[2] the public, the Government, and the oil companies already appreciate the gravity of the situation that will result when the domestic supply becomes so depleted as to fail to meet demands.[3] Those who look beyond periods of temporary overproduction, realize that even with conservation of existing supplies and increased recovery from present producing oil sands, the problem of furnishing sufficient oil to meet the inevitable and rapidly increasing demands[4] is indeed of prime importance. The following statements reflect the trend of opinion on the petroleum situation in the United States during the past five years.

At the Annual Meeting of the American Society of Mining and Metallurgical Engineers, held in 1920, a paper dealing with international aspects of the petroleum industry, was presented by Mr. Van H. Manning, Director U.S. Bureau of Mines. It may be noted that, in the opinion of many, references to oil-shales may be extended to include bituminous sands also. The following extracts are from the above paper:—

> In substance, the international aspects of the petroleum industry as these relate to the United States, are as follows: The domestic production is not keeping pace with the domestic demands; our best engineering talent warns us of the imminence of a decreased production by our oil wells, although more oil is needed; and the only practical source will be the foreign fields. . . .
>
> Petroleum has become, during recent years, one of the essentials of our social and industrial life. All civilized countries recognize that the world is dependent on petroleum as on nothing else except textiles, food stuffs, coal, and iron. To-day, the tendency is toward an ever-increasing consumption of petroleum and its products as new and more efficient uses are found for them. The utilization of petroleum is extending more and more into the structure of our civilization. Consequently, it

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[1] Consumption of fuel oil by merchant vessels and U.S. Navy.

	1924 barrels	1923 barrels	Per cent increase
By merchant vessels	73,031,000	62,825,000	16·2
By U.S. Navy	6,300,000	5,200,000	21·2
Total	79,331,000	68,025,000	16·6

[2] The American Petroleum Institute estimates the world's petroleum production in 1924 at 1,013,139,000 barrels, compared with 1,018,900,000 barrels reported by the U.S. Geological Survey for 1923, a decrease of 5,761,000 barrels or 0·6 per cent.

The United States produced 714,000,000 barrels in 1924, or 70·5 per cent of the total world production. In 1923 the United States produced 732,407,000 barrels, or 71·9 per cent of the world production in that year. The United States production in 1924 decreased 18,407,000 barrels, or 2·5 per cent.

Mexico produced 139,587,000 barrels in 1924, or 13·8 per cent of the world production. In 1923 Mexico produced 149,585,000 barrels, or 14·7 per cent of the total production in that year. The decrease for Mexico in 1924 amounted to 9,998,000 barrels, or 6·7 per cent.

In 1924 the United States and Mexico combined produced 84·3 per cent of the world production, and in 1923, 86·6 per cent.

[3] Hamor, W. A. The Problems of the Petroleum Industry; Chem. & Met. Engr. Sept. 8, 1920.
Smith, George Otis; A Foreign Oil Supply for the United States; Am. Inst. Min. & Met. Engrs.; January 1920.
Dowling, D. B. "The Possibilities of the Oil Resources of Canada." Trans. Royal Can. Institute, Vol. XIII, No. 1. 1921.
White, Dr. David: The Oil Supply of the World. Mech. Engineering, Sept. 1922.
Ibbotson, H. I. Oil Production in the Future; South African Journal of Industries; Feb. 1924.
Publications of American Petroleum Institute, 1923-4-5.
White, Dr. David. "Oil Reserves of the United States." Trans. Am. Inst. Min. and Met. Engrs., Vol. 68, 1923.
Rousseau, Admiral H. H. "The Naval Oil-Shale Reserves." Mining Congress Jour. March, 1925.
Sears, Julian D. "Engineers and the American Petroleum Situation." Mech. Engineering, Jan. 1925.
McKee, Ralph H., and others; Shale Oil; Chemical Catalog Co., New York, 1925.

[4] Statistics published by the American Petroleum Institute illustrate in a striking manner the rapidly increasing rate of consumption of crude petroleum and petroleum distillates.

American Petroleum, Supply and Demand; A Report to the Board of Directors of the American Petroleum Institute by a Committee of Eleven Members of the Board.

becomes a matter of the gravest concern whether we can go on building up an industrial and social structure dependent on petroleum unless we make provision for obtaining the necessary supplies. Unlike foodstuffs and textiles, the world's supply of petroleum is definitely limited; moreover, it is, like coal and iron resources, a wasting asset. But petroleum is a liquid, is by nature migratory, can be quickly extracted, and an oil field is readily exhausted; whereas coal and iron are extracted more slowly and, by prospecting, reserves can be blocked out for the years ahead. Oil fields once discovered are developed almost immediately; within a short time the peak of production is passed and decline sets in. We are constantly relying upon the discovery of new fields, at the moment unknown, to make up for the decline and depletion of those that are proved. Thus, we are living a hand-to-mouth existence and although during the past decades we have been very fortunate in making opportune discoveries—first Cushing, then Kansas, and then northern Texas —each of which has made up for a threatened deficit, the time must inevitably come when fortune will forsake us and the needed new production will not materialize. Then we may find ourselves suddenly thrown upon the mercy of the nations that control foreign sources of supply.

Few of us realize in how many ways petroleum products serve our daily needs. Petroleum in one form or another is used in every household; gasoline for the motor car, lubricating oils for bearings, kerosene lamps or paraffin candles for illumination. Not one of us can sit back and say that an adequate supply of petroleum is not a personal concern. Perhaps a recent statement appearing from enemy sources may convey most convincingly the importance of petroleum in modern life. Ludendorff, in his book on the late war, in speaking of the Rumanian campaign, says "As I now see clearly, we should not have been able to exist, much less carry on the war, without Rumania's corn and oil, even though we had saved the Galician oil fields from the Russians." . . .

Clearly we must seek other sources of supply to make up the balance between domestic production and domestic needs. Enormous deposits of oil-bearing shales occur in the western states, in the Cretaceous formations of the Rocky Mountain region. The U.S. Geological Survey estimates that the shales in the states of Colorado, Wyoming, and Utah alone contain many times the recoverable oil present in our oil fields before well drilling began. But the oil in these shales is not immediately available. The extraction of oil from the shales on a commercial scale under existing conditions in the United States is still in an experimental stage. We do not know, as yet, whether these shales can be developed profitably under the present conditions, nor under what conditions they can be developed. Furthermore, it will take many years, even under favourable conditions, to obtain from these shales enough oil to replace a considerable part of that now obtained from wells.

I do not wish these statements to be interpreted as reflecting on the prospects of the shale industry, but simply wish you to realize that the production of oil in the quantities demanded by present-time needs would require development on a tremendous scale and would require the mining of hundreds of millions of tons of shale each year, the annual amount being more than half the annual tonnage of coal now mined. There is no evidence that shale oil can be produced on such a scale at present prices and, therefore, to satisfy our petroleum needs by oils from shales involves higher prices for petroleum products. Moreover, our oil shales occur in sparsely populated regions, remote from centres of large consumption. Oil shales constitute a reserve that, fortunately, seems to provide ample protection against an ultimate future but they cannot be used to meet the present situation. . . .

At the Annual Meeting of the American Institute of Mining and Metallurgical Engineers held in New York in February, 1922, a symposium dealing with the petroleum situation in the United States and foreign countries was presented[1]. A number of the papers illustrated in a striking manner the remoteness from present transportation of many of the fields in which petroleum is now being sought as well as the oppressive legislation

[1] Trans. Am. Inst. Min. & Met. Engrs. Vol. 68.

imposed on operators in certain foreign countries. The following extracts are from the paper presented at the above meetings by Dr. David White, Chief Geologist, U.S. Geological Survey.

The Director of the U.S. Geological Survey, in March, 1921, requested the American Association of Petroleum Geologists to co-operate in the preparation of new estimates of the oil remaining in the ground. With the members of this co-operative committee, state geologists, regional geologists, consulting specialists, and geologists and engineers attached to many companies worked both independently and through sub-committees. The reports for districts, counties, fields, etc., after review by local or state committees, were discussed by the joint co-operative committee in conferences that, in some instances, were attended by the original compilers of estimates for the states or smaller areas. Finally the data were reviewed and the figures revised by the joint co-operative committee, so that the totals given[1] represent the opinion of the committee which was composed of F. W. DeWolf, W. E. Wrather, Roswell H. Johnson, Wallace A. Pratt, Alexander W. McCoy, Carl H. Beal, C. T. Lupton, G. C. Matson, K. C. Heald, W. T. Thom, Jr., A. E. Fath, Kirtley F. Mather, R. C. Moore, and David White, chairman.

Oil geologists and engineers understand well the speculative nature and the chances of error that must attend estimates of the petroleum in the ground when they cover not merely prospective territory, but possible territory. Neither the character nor the magnitude of the factors of uncertainty is to be disguised. Further, the inevitable differences of opinion between geologists of equal rank and experience must also be taken into account. Against these must be placed the personnel of the committee and the advantage of full discussion and conferences attended, in most cases, by geologists especially familiar with the regions in question; and the fact that the figures published represent the combined individual judgments of the members of the committee. The estimates given are undoubtedly based on more complete data compiled by better methods than those previously prepared for this country. No such appraisal has been prepared for any other country; for most countries, the development and the records of tests, exploration and production are not so long established nor so adequate for such calculations. These estimates, the preparation of which extended through the greater part of a year, may be regarded as the best now obtainable. . . .

Of these 9,150,000,000 barrels of oil over 4,000,000,000 barrels are in the heavy-oil group, including fuel oils and 5,000,000,000 barrels in the light-oil classes. The Lima-Indiana field is credited with 40,000,000 barrels, and approximately 725,000,000 barrels are believed to remain in the Appalachian states. These estimates relate to oil in the ground recoverable by present methods. It was the unanimous conclusion of the committee that, except for small areas in western New York and northern Pennsylvania where "water drive" has long been in operation, any attempt to forecast quantitatively the increased recovery, perhaps 40 to 80 per cent, to be won in the different regions, fields, and pools by improved methods of recovery would introduce an element of uncertainty far greater than that entering into the present estimates.

The total exceeds the estimate last published by the writer by 2,000,000,000 barrels. The anomaly of growing estimates simultaneous with exhausting resources is explained by the widespread wildcatting during and since the war; by the vastly greater volume of information touching all areas available for use by a larger and more diverse body of oil geologists in the committee; by the more thorough methods of calculating oil reserves and the experience developed in their use; and by the fact that the earlier estimates were far more conservative.

It is more than probable that, in most instances, the actual yields of the producing states will exceed the estimates, but it is equally probable that for the older producing states the excess will not be large compared to the whole amount. Greater uncertainty attends, of course, the states of present small production and less complete exploration and development. . . .

No estimate is submitted for Alaska, as to which recent geologic reports are in general very favourable.

[1]The estimated oil reserves of the United States on January 1, 1922, were then itemized by States or Regions indicating a total value of 9,150,000,000 barrels.

It may be noted that the oil reserves of the United States, as estimated by the committee, comprise one-seventh of the oil reserves of the world, as estimated by Stebinger and White. From these figures, it would appear that this country, with an original content of about 14,000,000,000 barrels, was much fuller of oil than other parts of the earth or, which is more probable, the estimates for some of the other countries are too low.

Contrary to the statement that the oil reserves of the United States will be exhausted in 20 years, a long time will be required for the exhaustion of our oil-fields. Though the estimated reserves would not survive 20 years if they could be made available so quickly as to meet the demands, even at the present rate of consumption, some of the oil pools are not likely to be discovered within a generation and some will be producing 75 years from now. Therefore, if the oil cannot be so rapidly found and extracted from the ground, we must the sooner pass a point beyond which will follow a long, though naturally variable, decline.

As our domestic production has been increasing annually a little more than 6 per cent during normal years, with occasional special jumps, a much larger increase in the amount of imported oil has been necessary to fill the gap between domestic production and domestic requirements. While the output of the fields in the United States in 1913 was 248,000,000 barrels, an 11 per cent increase over that of the preceding year; in 1918, 356,000,000 barrels, 6 per cent increase; 1919, 378,000,000 barrels, 6 per cent increase; 1920, 443,000,000 barrels, 17 per cent increase; and 1921, 470,000,000 barrels, 6·1 per cent increase; our importations of petroleum, mainly from Mexico, for the same years were, respectively, 18,000,000 barrels, 141 per cent increase; 38,000,000 barrels, 25 per cent increase; 53,000,000 barrels, 40 per cent increase; 106,000,000 barrels, 101 per cent increase; and 125,000,000 barrels, 18·2 per cent increase. The situation is as alarming as it is striking.

We must have foreign oil. On the other hand, the importation of foreign oil may reach a point that, through oversupply, is harmful to the oil industry of one part of the United States, however profitable it may be to another. The effects of oversupply on our domestic production last year cannot be accurately appraised, for one cannot readily calculate the quantity nor the market prices of oil that would have been produced in the United States in 1921 had there been a deficiency of oil for importation. Such a deficiency, it is reasonable to believe, will be experienced when Mexican production is forced to shift from a comparatively small number (say 300) of stupendously spectacular gushers to wells more nearly of the normal type. An idea of the magnitude of the task of developing 175,000,000 barrels annual production in Mexico from wells of the ordinary types and the years required may be drawn from the fact that in 1908, when the production of the United States first reached that amount, over 140,000 wells contributed the oil. Geologists may forecast the geologic possibilities of future Mexican production from salt domes, from anticlinal sands, or from cavernous limestones, but only the driller and the oil-field engineer can calculate approximately the great deductions to be made in this number of wells on account of necessary rapidity of development, freshness of production, etc. No one can forecast the efficiency of the oil companies and the measure of their success in insuring the oil-using industries against an hiatus in oil production in Mexico. The peak of production in the United States is likely to be passed during the early part of the period of overtaxing strain on the American oil-fields consequent to the pronounced deficiency of imported oil, which in turn may be expected to result from the slump that must some day come in Mexican production. If sufficient time is given for the development in other regions of oil available to our people before Tamosopo gusher supplies are too far exhausted, and if this time is diligently utilized by American oil companies, the strain in the domestic oil market will be less acute and less disastrous.

Following the creation on December 19, 1924, by the President of the United States, of the Federal Oil Conservation Board, a Committee of Eleven was appointed in January, 1925, by the Board of Directors of the American Petroleum Institute, for the purpose of investigating the oil industry and resources of the United States. The survey by this Committee has been countrywide, engaging not only the attention of a great

number of operators, experts and scientists within the industry, with personal and first hand knowledge of conditions in the numerous oil-producing regions of the country, but also that of foremost experts in other matters which have a direct bearing on the future of oil.

In the report[1] recently issued by this Committee, the following summary of conclusions appears:—

1. There is no imminent danger of the exhaustion of the petroleum reserves of the United States.

2. It is reasonable to assume that a sufficient supply of oil will be available for national defence and for essential uses in the United States beyond the time when science will limit the demand by developing more efficient use of, or substitutes for oil, or will displace its use as a source of power by harnessing a natural energy.

3. Current supply and demand cannot stay in balance, since the amount of both supply and demand are constantly changing. Generally, current supply will exceed or be less than current demand, creating surplus or shortage; either condition will be reflected in price, but price will in time correct either condition.

4. Petroleum recoverable by present methods of flowing and pumping from existing wells and acreage thus proven consist of five billion, three hundred million (5,300,000,000) barrels of crude oil.

5. It is estimated that after pumping and flowing there will remain in the area now producing and proved twenty-six billion (26,000,000,000) barrels of crude oil, a considerable portion of which can be recovered by improved and known processes such as flooding with water, the introduction of air and gas pressure and mining, when price justifies.

6. Improved methods of deep drilling below oil sands now producing will disclose in many areas deposits not hitherto available, which will be tantamount to the discovery of new fields. Improved methods of producing have been perfected which will make possible recovery of oil from these lower levels. The limit of deep drilling has not been reached.

7. The major oil reserves of the United States lie in some one billion, one hundred million (1,100,000,000) acres of lands underlain by sedimentary rocks, and not fully explored, in which geology indicates oil is possible. With extended search new supplies will be found therein.

8. The nation has an additional reserve in the vast deposits of oil shale, coal and lignites from all of which liquid fuel and lubricants may be extracted if and when the cost of recovery is justified by the price of these products. These deposits are so huge that they promise, under conservative estimates, an almost unlimited supply.

9. While this report is confined to the petroleum supply and demand within continental United States the importance of imports cannot be ignored. Countries to the south are known to have large petroleum resources, for the output of which the United States is a natural market and the supply therefrom must inevitably have its influence on the consumption of American reserves.

10. The availability of future petroleum supplies from the vast area of land mentioned above depends upon adequate incentives to the exploration which in the past has given the nation a sufficient supply of petroleum, in peace and in war, throughout the history of the oil industry, from its inception in 1859.

There must be:

(*a*) Security in the ownership of oil lands and of the right to lease.

(*b*) Conditions of exploration and development by owners or lessees permitting exercise of initiative, liberty of action, the play of competition and the free operation of the law of supply and demand.

(*c*) Prices that will provide a return to producers, refiners, and distributors commensurate to the risks involved and the capital invested.

11. The supply of petroleum will be made to go much further through more efficient utilization. Automotive experts state that the mileage of the motor car per gallon of gasoline may be doubled through structural mechanical changes, when price justifies such changes. Improved mechanics will also result in smaller consumption of lubricants.

[1] American Petroleum; Supply and Demand. A Report to the American Petroleum Institute.

12. Through improved methods, principally the process known as "cracking," the refining branch of the industry has already increased the yield of gasoline, now the major product of petroleum. Through further improvements and extensions the supply of gasoline will be augmented still further by the "cracking" of fuel oil. In consequence the supply of fuel oil will be correspondingly diminished, thus eventually removing fuel oil from competition with coal.

13. Waste in the production, transportation, refining and distribution of petroleum and its products is negligible.

Referring to the use of substitutes for present well petroleum, the Committee of Eleven comments as follows:

Time of Substitutes Use.—If and when the cost of recovery of oil and gasoline from shale, coal and lignite will permit this oil and gasoline to be sold in competition with similar products from present and other sources of supply, then, and then only, will these products be commercially available.

It may be noted that criticism of the conclusions arrived at by the Committee of Eleven has already appeared.[1]

It is evident that the production of petroleum from Alberta bituminous sand is a question that should be given careful consideration. Such a production would apparently be relatively free from certain well-recognized hazards that attach to the present production of petroleum. Among these may be mentioned the uncertainty of locating oil pools, the uncertainty respecting amortization, the fluctuating price hazard due largely to uncertainty of uniform production,[2] and the danger of new discoveries more advantageously situated with respect to markets. Discovery of petroleum pools of commercial importance in western Canada would doubtless adversely affect and delay for a time development of the Alberta bituminous sands.

A plant for recovery of crude petroleum would of necessity be established in the immediate vicinity of supplies of raw material, but the location of a site for preparation of various refined petroleum fractions, would be determined largely by freight charges and fuel supply. Obviously reduction in bulk and gravity of product shipped would be favourably reflected in reduced transportation and storage costs. The maximum profit would be possible through control of all operations from initial production, to placing the finished products on the market.

Results of Distillation

In 1913, the writer distilled a number of samples of bitumen separated from Alberta bituminous sand.[3] Apparatus used was that recommended by the American Society for Testing Materials, but heat was applied by means of a hot-air bath, instead of direct heating from below.

The average total percentage of oil thus distilled, including all fractions, was 69 per cent by weight of the original bitumen. The coke residue was equivalent to 23·7 per cent of the original bitumen. The remaining 7·3 per cent represent uncondensed fractions, losses in apparatus, etc.

[1] Mining Congress Journal, December, 1925.

[2] Lack of assurance of supply rather than the price, has hindered the expansion of the fuel-oil market. In the fall of 1918, there was a fuel-oil famine; in the spring of 1919, a surplus; early in 1919, another famine; and in the fall of the same year, another surplus. Such rapid changes obviously deter prospective consumers. The oil producer is not perturbed by the prospect of possible development of bituminous shale and bituminous sand reserves. He knows that these will become important competitors only when the price of oil will be quite satisfactory to him.

[3] Bituminous sand used for distillation purposes, had been excavated from exposures 18 months previously. For relative specific gravity and viscosity of bitumen derived from weathered and unweathered material see Chapter II, Section V.

Analysis of coke—	Per cent
Volatile	6·5
Ash	2·0
Fixed carbon	91·5
	100·0

The general fractions derived from distillation of 100 c.c. of crude petroleum have been grouped as follows:—

Fractions	Temperature	Amount of oil c.c.	Sp. Gr.	Paraffin scale	Unsaturated (polemerized using 37 normal H_2SO_4)
	°C.			per cent	per cent
1st	0—110	2·5	0·85		
2nd	110—275*	73·0	0·88	0·29	30·0
3rd	300—330	17·5	0·91	0·09	40·9
4th	330—360	2·5	0·96		

*(Chiefly between 250° C. and 275° C.)

In 1916, a retort was designed and constructed at the Mellon Institute, Pittsburgh. The mechanical operation of this retort was satisfactory, but the recovery of petroleum did not correspond with the estimated petroleum content of the bituminous sand treated.

In using the above retort, a temperature of 350° to 360° C. was maintained for 1 hour and 15 minutes during which time the sand was agitated continuously. During the greater part of this period the lower half of the retort was at a dull-red heat. In no instance, however, did the actual yield of petroleum exceed 14 Imperial gallons. On opening the retort, large volumes of oil gas were liberated, and the partly distilled sand, when discharged, still contained a considerable percentage of petroleum. On the lower inner surface of the retort a thin film of hard dry coke had formed to a thickness of $\frac{1}{8}$ to $\frac{1}{4}$ inch.

The conclusion arrived at as a result of a number of trial runs was that all of the bituminous sand did not actually reach the temperature referred to, namely, 360° C.

The retort was originally heated from below, and all of the coke scale was found deposited on the lower half, the inner surface of the upper half of the retort being quite clean. It, therefore, appeared probable that a different system of heating and a very close contact between the agitation blades and the walls of the retort, would result in more efficient recovery of petroleum. Accordingly, the system of heating was modified by constructing a firebrick arch above the retort and heating from above. Using the modified method of heating, three additional distillation runs were made. The recovery of crude petroleum was equivalent to 19·3 Imperial gallons per ton of crude sand. The discrepancy between the actual and the theoretical yield (equivalent to 3·4 gallons per ton of crude sand) may be attributed chiefly to imperfect condensations rather than to incomplete distillation.

ANALYTICAL RESULTS

The crude oil obtained by the destructive distillation of Alberta bituminous sand in the oil-shale retort, appeared to be similar to asphalt-base petroleum; it has a specific gravity of 0·9194 at 20° C. or 22·27° Bé., and a calorific value of approximately 17,000 B.T.U. per pound. By the above methods the actual yield from bituminous sand containing 15 per cent of bitumen amounted to approximately 19·3 Imperial gallons per short ton (23·2 U.S. gallons).[1]

The crude oil showed the following analytical characteristics:—[2]

Distillation by Engler's Method

Temp.	Per cent (by volume)	
To 75° C.	0·4	
75°—100° C.	1·5	
100°—125° C.	2·7	
125°—150° C.	3·5	
		8·1
150°—175° C.	3·5	
175°—200° C.	4·1	
200°—225° C.	2·9	
225°—250° C.	4·7	
250°—275° C.	5·4	
275°—300° C.	10·0	
		30·6
300°—325° C.		6·0
140°—175° C. at 8 mm.	4·9	
175°—225° C. "	17·5	
225°—275° C. "	16·0	
275°—325° C. "	*8·6	
		47·0
† Asphalt and loss		8·3
		100·0

* This fraction contained 0·9 per cent of paraffin wax (melting-point 55° C.).
† Penetration of asphalt 5; (100 g./5 sec./25° C.).

Specific Gravities of the Unrefined Distillates

Fraction °C.	Sp. Gr. 20° C.	Flash-points (Pensky-Marten apparatus) °C.*	Viscosity at 20° C. (Engler)
To 150°	0·7395	....	....
150—275°	0·8403	....	....
275—300°	0·8943	....	....
300—325°	0·9066	....	....
Residue above 300° C.	....	123	....
140—175° at 8 mm.	0·914	130	1·86
175—225° "	0·932	165	3·79
225—275° "	0·964	209	43·7
275—325° "	0·991	245	67·9

* The three upper fractions of lubricating oil darkened somewhat after obtaining the flash-points.

[1] It is considered that in actual efficient commercial practice a yield higher than 19 Imperial gallons per ton of 15 per cent bituminous sand can be obtained.

[2] The analytical examination of the crude oil was conducted by Mr. I. W. Humphrey, Industrial Fellow on the Petroleum Fellowship in the Mellon Institute. A complete exhibit of refined fractions was prepared.

Calorific Value

The residue above 300° C. possessed a calorific value of 9,930 calories per gramme. As noted, the crude oil had a calorific value of approximately 17,000 B.T.U.

Refining Losses with 66° Bé. Sulphuric Acid

The following losses were observed when sulphuric acid equal in volume to 5 per cent of the oil was used in each refining:

Refining	Entire gasoline fraction*	Kerosene
	per cent	per cent
1	14·5	8·0
2	8·0	4·7
3	4·5	2·6
4	4·0	2·7
	33·0	18·0

* The odour of the gasoline was good after the first refining, but the colour was still dark after the fourth.

The kerosene behaved like the gasoline on refining.

Refining Losses on one Treatment

Fraction	Loss per cent
300°—325° C.	7·0
140°—175° C. at 8 mm.	4·2
175°—225° C. "	8·5
225°—275° C. "	12·5
275°—325° C. "	8·4

The gasoline and kerosene fractions were dark and had a highly cracked odour before refining, but the lubricants possessed no cracked odour and were of a reddish colour.

Treatment with Aluminium Chloride

The crude oil, when treated with 8 per cent of aluminium chloride added in small lots during ten hours slow distillation, gave 20·1 per cent of gasoline, specific gravity, 0·752 at 20° C., colourless and of fair odour.

From 160° to 300° C., the distillate was 15·1 per cent; the odour was good, but the product was slightly coloured.

From 300° to 325° C., the distillate amounted to 3 per cent, the odour was good and the colour was pale yellow.

The portion above 325° C. was poured off from the tar. It comprised 24 per cent and was not distilled.

The losses amounted to 37·8 per cent.

The crude gasoline, when treated with 2 per cent of aluminium chloride, lost 36 per cent.

The crude kerosene, when treated with 5 per cent of aluminium chloride, lost 32 per cent, was colourless and of a good odour.

Conclusions

Although crude petroleum derived from Alberta bituminous sand could be refined in toto for the production of gasoline, kerosene, 300° (C) oil, lubricating oils, and petroleum residuum, it appears desirable that, for primary and tentative development, only the output of gasoline and fuel oil be considered. A smaller investment and less experience are required for such a stripping or topping plant, and it is unlikely that serious difficulty would be encountered in disposing of the products therefrom.

In the above outline, the gasoline cut has been considered as the distillate up to 150° C. (302° F.), whereas in present commercial practice gasoline is cut around 175° C. (347° F.). On the latter basis, the yield of crude gasoline from the oil analysed would be 11·6 per cent instead of 8·1 per cent, with, of course, a corresponding decrease in kerosene stock from 30·6 per cent to 27·1 per cent. It is also considered that the loss of 33 per cent, allowed in the refining of gasoline, is high. Under practical working conditions, much less unsaturated bodies would probably be produced, and after the first refining, which leaves the gasoline with a good odour, the proper colour could be produced by steam-stilling instead of further acid treatment. Thus, instead of a yield of only $8{\cdot}1 \times (1-0{\cdot}33)$ or 5·4 per cent, it may be possible to get $11{\cdot}6 \times (1-0{\cdot}15)$ or 9·8 per cent of refined gasoline.[1]

The possibility of commercially recovering petroleum from crude bituminous sand cannot be intelligently criticised until further data are available. The information that has already been secured appears to be encouraging. Outstanding questions are: whether a dense material, such as crude bituminous sand, can be heated to the required temperature without undue expense, and whether complete distillation can be effected without producing an undue percentage of unsaturated bodies. These questions can only be answered by further experimental work on a larger scale. The introduction of steam, or possibly the use of a part vacuum, suggests obvious advantages.

Indeed, the question might be asked, whether the recovery of the bitumen unchanged or its recovery in a condition in which it is already converted into its finished products should be considered of primary importance. The use of a distillation process, either with or without decomposition, immediately brushes aside the many problems presented by hot water separation, but it brings with it other problems. However, these latter problems are apparently chiefly of a mechanical nature, and have to do mainly with the handling of the raw material in and through the distillation apparatus, and the disposal of mineral residue. Depending on the results desired, distillation can, of course, be carried on with all variations from the most severe destructive distillation to ordinary distillation where every attempt is made to reduce decomposition to a minimum. Where all decomposition is to be eliminated as far as possible, resort may be had to vacuum distillation, or, better still, to steam distillation. With ordinary liquids, the choice of the particular kind of distillation for given desired results need ordinarily have no limitation other

[1] It is stated that as a result of more recent investigation by private interests, a very much higher yield of gasoline has been obtained.

than that of comparative cost. In the case of bituminous sand, however, this choice may be somewhat limited by the mechanical problems involved. Unlike liquids, in which circulation promotes the uniform distribution of the heat and thus prevents, to a large extent, the overheating and consequent damage of the part closest to the heating zone, bituminous sand will have no circulation, except such as may be provided by the design of the apparatus, or by other mechanical means. Unless very special precaution is taken in this respect, decomposition is certain to take place, whether it is desirable, and there can be no question that, under these circumstances, the problem becomes very difficult.

The evaporation apparatus should be continuous in operation, and preferably a closed system, except for communication to the atmosphere through the condenser, thereby assuring its working under atmospheric pressure, and at the same time preventing the entrance of air as well as the escape of vapours. The raw material need not be finely divided, say, three to six inches, depending on the size of apparatus. Undoubtedly, at some temperature below melting, probably slightly above 100° F., the bituminous sand would become sticky and would tend to hang and clog the apparatus unless special precaution—such as the introduction of necessary steam jackets—was taken. This tendency might be largely overcome by allowing the force of gravity more or less free action or by application of mechanical force when working the material downward through the apparatus. The feed of crude sand and the removal of waste sand can easily be made continuous by alternate use of duplicate chambers, or, preferably, by use of elevators and screw-conveyers with fluid seals at points communicating with the atmosphere. The seal for the entering crude sand could be either gas-oil made in the process, or water, and that for the discharge of the waste sand should be water.

There are several methods by which the sand might be passed through the evaporating or heating zone. Broadly speaking these may be divided into two classes, namely, those actuated by gravity, and those using mechanical power. If passage is allowed to take place under the influence of gravity alone, the apparatus employed may be either a vertical stack, or it may be of a zigzag form. If mechanical power is to be used, it would seem necessary that the sand be made to pass through either by rotating a suitably inclined tube, or by forcing it through a stationary tube by means of a screw-conveyer. Apparently the rotary tube would be quite out of the question, as it would be almost impossible to make, and maintain in operation, gas-tight seals at its ends. The vertical gravity-flow tube would certainly be the simplest to build and to operate, but would not be so efficient for heat transfer as the zigzag type. It would be more difficult to thoroughly mix the combustion gases and bring them all into intimate contact with the case of a zigzag apparatus. Also, the sand in the vertical tube would virtually pass down and out the vertical tube in the same relative place in its cross-section to that in which it entered; that is, sand entering near the centre would pass through and out near the centre; whereas, in a zigzag apparatus, the sand would tend to be tumbled about and its relative position in the tube changed when passing from one inclined section to another. A two-stage process involving mechanical separation

of bitumen, followed by distillation of the partly or wholly purified product, would obviously possess certain distinct advantages.

The problem presented by suggested distillation of liquid hydrocarbons from bituminous sand was discussed with a number of competent petroleum technologists, and outlines of various types of distillation apparatus together with cost estimates prepared. It was felt, however, that data available, were too incomplete to warrant the expression of an opinion regarding the probable commercial success that might be expected from distillation of crude bituminous sand.

CHAPTER III

I. POSSIBLE MARKETS FOR ALBERTA BITUMINOUS SAND, ASSOCIATED HYDROCARBONS, AND FOR WASTE SAND

Asphaltic materials are used extensively for a variety of purposes other than paving. Their dissociation and reconstruction constitute an important feature of industrial research.[1]

The finer grades of asphalt are used extensively in the manufacture of paints and varnishes and as an electrical insulator. Both natural and artificial asphalts are used in making roofing preparations, the former being preferable. Asphalt is also employed in the manufacture of rubber, waterproof cloth, in enamelling iron, and as a binder for briquetting fuel. Of even greater importance is the constantly increasing demand for light mineral oils.

Conditions governing the use of asphaltic materials are continually changing. The following statements relating to what is, as yet, so far as the Alberta bituminous sand is concerned, an undeveloped industry, must therefore be considered as somewhat speculative. They are, however, based on information at present available. No attempt is here made to discuss methods employed in the preparation of commercial products, since these are fully described in an extensive published literature.

One of the weak points in any argument advocating the development of the Alberta deposits of bituminous sand, is the absence of accurate data regarding markets which may be available for:—

1. Crude bituminous sand.
2. Separated and refined bitumen.
3. Waste sand from water separation process.

1. CRUDE BITUMINOUS SAND[2]

This includes the use of crude bituminous sand for the surfacing of streets and highways, the construction of sidewalks and a variety of other types of wearing surfaces, and possibly the preparation of asphalt mastic. The extent to which it may be used for such construction will be controlled largely by freight rates.

[1] As Senior Industrial Fellow of the Mellon Institute of Industrial Research, Pittsburgh, Dr. J. H. Young, has been engaged on behalf of the H. H. Robertson Company of Pittsburgh, Pa., in studying various bitumens and their possible applications for special industrial purposes. In the writer's opinion, a study of possible commercial applications of bitumen derived from Alberta bituminous sand, would prove of practical value if undertaken by a qualified investigator.

[2] The present market for solid and semi-solid bitumens in western Canada is comparatively small, but should be capable of material expansion, when various applications of what is admittedly a high-grade bitumen, become more widely recognized. The following statement indicates the quantity of asphaltic materials entered for consumption in Canada, at Winnipeg, Calgary, Edmonton, Regina, Saskatoon, New Westminster, and Vancouver:—

Asphalt, Solid

	1911-12	1912-13	1913-14	1921-22	1922-23
Value	$ 139,586	$ 276,431	$ 127,446	$ 64,506	$ 72,197
Tons	7,857	17,814	7,363	....	3,367

Asphalt, not Solid

	1913-14	1921-22	1922-23
Value	$ 24,412	$ 339	$ 11,336

In Canada, the application of asphalt mastic in connexion with various kinds of architectural and engineering construction is increasing each year, but no accurate data regarding consumption are available. It is believed that mastic prepared largely from Alberta bituminous sand, will be found suitable for a number of recognized uses.

2. SEPARATED AND REFINED BITUMEN[1]

(a) As Asphalt Cement in Wearing Surfaces for Streets

During the fiscal year 1912-13,[2] 12,467 tons of asphalt cement were imported into Alberta, Saskatchewan, and Manitoba, and 9,550 tons entered Canada at British Columbia ports. Assuming that 50 per cent of the latter amount was transhipped to points in the Prairie Provinces, we have a total available market for 17,242 tons of asphalt cement. This material would represent the bituminous content of approximately 125,000 tons 14 per cent crude bituminous sand. To this may be tentatively added, for sidewalk construction, an estimated quantity of bitumen equivalent to 10,000 tons crude bituminous sand.

The use of asphalt in the United States is steadily increasing, but the trend is toward a greater utilization of asphalt manufactured from crude petroleum,[3] rather than toward a more extensive development of the deposits of natural asphaltic materials. The factors that are bringing about this change in the asphalt industry are chiefly economic in their nature, now that the experimental stage in the utilization of the artificial product has been passed. The cost at which large refineries at tidewater, or at interior points adjacent to the source of asphaltic oil, can supply an efficient substitute for the natural asphalts practically at the points of consumption, is so low that only natural material of the highest grade, favourably situated with regard to quarrying, mining, and transportation, or of such a character as to be in demand for special purposes, can successfully compete with the manufactured material. In certain localities remote from sources of asphaltic petroleum, but adjacent to deposits of suitable material in the form of asphaltic sandstone or limestone, the natural rock asphalt retains its precedence.

This statement of general conditions in the United States is of direct interest in connexion with the proposed development of Canadian deposits. It should be remembered, however, that the Alberta bituminous sand will compete in western Canada with petroleum residuum, under much more favourable conditions than has usually been the case when bituminous sand has competed with similar material in the United States. Thus, during the period 1913-24, residuum has sold for $23 to $50 per ton

[1] Publications of Asphalt Association, New York.
[2] The fiscal year 1912-13 may be considered as representing pre-war conditions.
[3] Consumption of asphaltic materials in the United States, during 1922, exceeded by about 28 per cent that for any preceding year, and was almost double that of 1915. Of the 2,446,024 short tons reported for 1922 by the U.S. Geological Survey, 2,047,308 tons, nearly 84 per cent, was manufactured or recovered directly from petroleum. Consumption of domestic native asphalt and related bitumens amounted to 327,792 tons. The greater part of this tonnage consisted of bituminous rock containing only 6 to 15 per cent or less of asphalt proper. In 1924 production of bituminous rock having an average bitumen content of less than 10 per cent was 525,831 tons.
Mineral Industry, Vol. XXXIII; 1924.

in Alberta,[1] whereas, in many parts of the United States, during the same period, residuum has sold at the refineries at from $9 to $20 per ton.

It is of interest to note that crack fillers[2] for concrete road surfaces still call for research. Two lines of endeavour appear to interest practical road-builders. One is to secure a filler which will have the colour of the pavement, and so obscure, as far as possible, evidences of failure. The other is to secure a filler which will stick, and is obviously the more important. In the course of recent experiments in Iowa fourteen bituminous mixtures were tried. All were mixtures from which success might have been anticipated, but of the fourteen, only three proved satisfactory. Reference to results of the above investigation will be found in the report of the Highway Research Council, the conclusion of their special committee being that, " some practical method of making asphalt stick to the pavement, should be devised if possible." It appears that an opportunity is here presented for profitable investigation in connexion with possible uses for the bitumen associated with Alberta bituminous sand.

(b) Bituminous Paints, Cements, Varnishes, Enamels, and Japans[3]

Preliminary reports based on an examination of small laboratory samples, were received from the research chemist of one of the largest paint manufacturing companies in the United States, and from Dr. Walther Riddell of Pittsburgh. These refer to the possibility of utilizing bitumen separated from Alberta bituminous sand, as a basis for the preparation of certain varnishes and paints. Both of these reports indicate that the Alberta bitumen is well adapted to such uses. It is not clear, however, whether under present market conditions, and in view of the present high degree of specialization which characterizes the paint and varnish industry, the production of paints and varnishes from Alberta bitumen would prove attractive financially.

(c) Binder for Fuel Briquetting

The writer is not in a position to express an opinion regarding the desirability of utilizing Alberta bitumen as a fuel-binder. The following observations may, however, be of interest.

In certain parts of the United States asphalt is largely used as a fuel-binder. Low sulphur and paraffin content is essential. These features render the asphalts derived from Texas and California crude oils—as opposed, for example, to much of the Mexican crude—desirable as a fuel-binder. Indeed for an efficient binder, the paraffin content should be even lower than the permissible limit in street-paving specifications.

Asphalt for briquetting may be hard or soft.

Hard asphalt may be used in two different ways: first, in a melted state, using asphalt of 155° to 160° F. melting-point (cube-method, water-test); second, the asphalt is pulverized so as to pass a 60 or 80 mesh, and then mixed with the coal. By the latter method it is possible to briquette very finely pulverized coal with a smaller percentage of binder

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[1] Cost of petroleum residuum (oil asphalt) in Edmonton (1924) was $34.46 per ton in tank cars.
[2] Concrete Crack Fillers; Engineering News-Record, March 12, 1925.
[3] Abraham, Herbert, Asphalt and Allied Substances, Chap. 27. "Physical Characteristics of Paint Coating," R. S. Perry; Am. Inst. of Architects, Michigan Chapter, June 4, 1907.

than would be necessary if liquid or melted asphalt were used. The melting-point of the pulverized asphalt is usually about 180° F. This depends, however, on the quality of the asphalt, since some asphalts will not pulverize or fracture readily, even though their melting-point be much higher than 180° F. The question of penetration is not essential in testing asphalts for briquetting purposes. Any asphalt used should be quite liquid at 212° F. For this reason asphalts derived from the distillation of petroleum usually give best results.

Soft asphalt, owing to its low melting-point, does not make a sufficiently hard briquette,—a defect which may be remedied by the addition of flour or other suitable material. The addition of flour tends to reduce the smokiness of the fuel. This is of importance in considering most of the coals of the Prairie Provinces, which consist mainly of lignites, sub-bituminous, and bituminous varieties.

Considering the bitumen derived from the Alberta bituminous sand, four points may be noted:

Melting-point. The bitumen as separated from the crude sand is very soft and of a low melting-point. The melting-point can be increased to 180° F. (cube-method, water-test), and the hardened asphalt then used either in a melted or pulverized condition. If it appeared desirable to harden the Alberta bitumen, the recovery of the low-boiling fractions would be entirely feasible.

Cost. It appears that separation of bitumen from bituminous sand will be feasible commercially, and at a cost[1] which will permit of competition with oil residuum for paving construction, and for other recognized uses.[2]

In the use of asphalt as a binder, it is usually considered that 1 to 1½ per cent less is required than when using coal-tar pitch.

Impurities. Of four samples of separated bitumen examined, the maximum paraffin content did not exceed 1 per cent. In three of these four samples the sulphur content was less than 2 per cent; in the fourth sample it was 4·8 per cent. In two other samples (see Chapter II) the sulphur content was 4·3 and 7·4 per cent respectively.

As noted elsewhere (Chapter II) sulphur is present as white sulphur compounds and in the form of iron pyrite. Fragments of iron pyrite, ranging in size from minute grains to pieces several pounds in weight are fairly common. The larger fragments could probably be separated from the crude bituminous sand by passing it over some form of steam-heated grizzly. The finer particles might be partly precipitated from the refined bitumen in heated settling-tanks.

It is considered by some that asphalt has an advantage over coal-tar pitch, for use as a binder in the manufacture of briquettes, in that the volatile matter given off during combustion produces a less objectionable odour than coal-tar pitch. Moreover, fumes and smoke from good asphalt binders do not condense or deposit in flues, water heaters, etc.

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[1] See cost estimate Bituminous Sands Company (Chapter VI, page 187).

[2] Present price (March 1925) of coal-tar pitch binders is from $10 to $12 per ton of 2,000 pounds, f.o.b. Sault Ste. Marie, Ont. Price of Imperial briquetting (asphalt) binder is $25 per ton f.o.b. Toronto, Ont., and approximately $45 per ton f.o.b. Calgary, Alta.

No data are available to the writer on which to base an accurate estimate of the market for fuel-binders that may develop in western Canada. This is due to rapidly changing conditions which affect the fuel situation. A larger market is yearly being found for higher grade lignites and sub-bituminous coals, both for domestic and for commercial uses.

In 1916, 1920, and 1925, the merits of bitumen separated from Alberta bituminous sand were investigated in various testing laboratories. In each instance the briquettes produced appeared to be entirely satisfactory.

(d) Electrical Insulation

Samples of separated bitumen were submitted to the research departments of two of the largest manufacturers of electrical apparatus in the United States. In each case an expression of opinion was asked regarding the probable value of the bitumen in connexion with the manufacture of such equipment.

The samples submitted were, of necessity, too small to base a final opinion on them, and reports were therefore inconclusive. Carbon and sulphur content will apparently prove to be controlling factors. Meanwhile the statement may be made that the bitumen from the Alberta bituminous sand has a high insulating value.

(e) Roofing Preparations[1] *and Bituminized Fabrics*[2]

A small sample of the separated bitumen was submitted to the Barret Company of New York. No written report was received since the sample was too small for complete determination. The opinion was expressed unofficially, that the results of the preliminary examination of the Alberta product were encouraging. Other analogous applications are in the preparation of adhesive compounds for built-up roofing and waterproofing work, as for membrane-waterproofing underground and also above ground; for pipe-dips and pipe-sealing compounds; for bituminous rubber substitutes; for moulding compositions as pre-formed joints and washers, bituminous cork mixtures, etc.; and waterproofing compounds for Portland-cement mortar and concrete.

3. WASTE SAND FROM WATER SEPARATION PROCESS

In considering the value of a sand as a possible basis for the production of glass, there is available for reference an extensive bibliography.

A study of this literature will, however, almost certainly lead to confusion in the mind of the average reader. This is due in part to the fact that writers have not always clearly specified the class of product to

[1] In 1924 approximately 928,552 tons of asphalt was used in the manufacture of prepared roofing in the United States. This is sufficient to cover more than 3,257,000 dwellings or over 325,000,000 square yards of roof. During the same year 165,000 tons of asphalt was used for waterproofing. At present there are, on the market, a great number of grades and types of prepared asphalt roofings, including asphalt shingles. This is apparently due to the remarkably rapid growth of a comparatively new industry.

[2] Abraham, Herbert. Asphalt and Allied Substances, Chapter 25. (1918). In this chapter, felted fabrics, woven fabrics, bituminous saturating compositions, bituminous coating and adhesive compositions, surfacings of mineral and vegetable matter, prepared roofings and shingles, and methods for using same are discussed.

which individual sands are adapted, and also to the fact that, in some instances, analyses are given which are no longer accepted in standard practice.

A number of analyses of sand have therefore been selected and in each instance the type of glass produced therefrom is indicated. Names of companies using these various materials are not given, but the product of each company is of recognized standard quality at present. It may be noted that, in point of cost, sand is the least important of any of the principal materials entering into the manufacture of glassware.

I. Chemical Analyses

—	SiO_2 per cent	Fe_2O_3 per cent	Al_2O_3 per cent	TiO_2 per cent	CaO per cent	MgO per cent	Organic matter and moisture per cent.
Sand used in making best grades of plate glass................	99·71 99·21 98·25	0·001 0·003 0·002	0·12 0·30 0·50	0·014	0·007 0·200 0·300	0·008 to 0·100	0·134 0·210 0·240
Permissible limits[1]....	90 to 100	0·10	2 to 3	....	up to 10	....	1
Sands used in manufacture of window, green, and amber glass................	99·40 99·62 99·54	0·0058 0·0047 0·0039	0·275 0·054 0·047	....	0·008 0·010 0·007	0·012 0·005 0·009	0·231 0·162 0·166
Permissible limits....	90 to 100	0·2	2 to 3	....	up to 10	....	1
Sands used in cheaper grades (beer bottles, etc.)................	99·11 99·17 97·50	0·010 0·011 0·500	0·355 0·366 1·500	0·221 0·234	0·009 0·011	0·023 0·019 0·500	0·19 0·18 ....
Permissible limits....	90 to 100	0·5 to 0·7	2 to 3	....	up to 10	....	1
Sand recovered from Alberta bituminous sands...............	95·50	0·35	2·25	....	0·500	0·23	1·50

In order to determine the manner in which the iron content was associated, sand tailings from Alberta bituminous sand were examined microscopically. Samples were also treated with solutions of caustic soda and of hydrochloric acid. From this examination it appears that, by washing, the iron content of the sand can be reduced to possibly 0·15 per cent. In this connexion it may be noted also that washing plants for the partial purification of glass sand are in general use.

[1] Permissible limits must be considered as somewhat arbitrary. Considerable difference of opinion also exists regarding various steps in glass making. (See "Some Fallacies and Facts pertaining to Glass Making," by R. L. Frink, Trans. Am. Ceramic Soc., Vol. 11, 1909).

From a consideration of the above data, it is evident that the sand tailings as derived from a successful extraction process, will be found satisfactory for the production of the cheaper grades of green glass (bottles, etc.), or if the sand is washed, for the production of white glass (window, plate, etc.).

II. Mechanical Analyses

Regarding screen analyses of sands, considerable difference of opinion also exists. By some it is claimed that draft carries away a part of the finer meshes; by others, that the finer grained aggregates, with their large volume of voids, introduce an undue amount of air.

Doubtless there is some justification for both claims, but apparently the importance of mechanical analyses of sand has been overestimated. Representative screen analyses of Alberta bituminous sand will be found on page 50, Chapter II.

Conditions, other than physical and chemical character of the sand itself, must therefore be considered. These considerations should include:—

(a) Amount of Sand Available. A commercially successful separation process would produce from 500 to 1,500 tons of waste sand per day.

(b) Location with Respect to Fuel Supplies. This will be considered elsewhere in this report. (Chapter V.)

(c) Conditions of Quarrying and Mining. The sand is a waste product, the disposal of which will be actually a source of expense.

(d) Location with Respect to Transportation. Successful commercial treatment of crude bituminous sand pre-supposes immediate proximity to rail transportation. Certain outcrops of bituminous sand are immediately adjacent to present rail transportation. Extension of the railroad for a distance of approximately 36 miles, would provide transportation to a number of the most promising areas north of McMurray.

(e) Location with Respect to Markets. The nearest centre of population, Edmonton, is 300 miles distant. Edmonton is a distributing point for a considerable area of northwestern Canada.

The cost of producing glass (1917) in the Pittsburgh district may be roughly divided as follows:—

Crude materials (sand, limestone, soda)..	40 per cent
Fuel..........................	40 "
Labour..	20 "

By comparing Pittsburgh costs with those of McMurray, corresponding percentages may be determined.

It may be noted that heavy beds of limestone immediately underlie the bituminous sand, and would be uncoverd during mining operations. Soda (salt cake and soda ash) are not locally available, but salt is being produced by the Alberta Salt Company at their McMurray plant.

Samples of sand, separated from crude bituminous sand by use of carbon bisulphide, were submitted to thirteen of the leading glass-manufacturing companies in the United States, together with a complete statement regarding conditions that would affect commercial development in the McMurray area. From reports submitted by these companies, it

appears doubtful whether the manufacture of glass from sand derived from Alberta bituminous sand would prove a financial success under present conditions. It is claimed that the making of glass has, in recent years, become highly specialized, no single factory making a wide range of varieties of articles. In order to specialize and to be in a position to make a maximum use of automatic machinery, and thus reduce labour costs, wide territory and extensive markets are essential. Such a market apparently does not exist in Alberta at present.

It is of interest to note that in Peru and in Utah, a material somewhat similar to bituminous sand contains uranium and vanadium. From correspondence with Mr. G. D. Van Arsdale, Consulting Chemist, Phelps, Dodge & Co., New York, and from a comparative study of samples from Peru and from McMurray, it appears improbable that either of the minerals mentioned will be found associated with the Alberta bituminous sand.

The investigation undertaken by the writer at the Mellon Institute, Pittsburgh, occupied a period of approximately six months. The work was discontinued early in 1917 as a result of war conditions, and was not resumed by the writer on his return to Canada in 1920. During the interval private research had made material progress[1], and sufficient interest had apparently been aroused in the problem to preclude the necessity for further laboratory investigation on the part of the Mines Branch.

II. USE OF BITUMINOUS SAND IN CONSTRUCTION OF WEARING SURFACES

(1) As Surfacing for Streets and Highways

Bituminous sand, modified by additions of clean sand or of clean sand and crushed rock.

In view of the many contributions that have appeared in pamphlets, journals, and other publications, it is quite unnecessary to enlarge on the subject of better roads. The following comment on "Benefits of Improved Roads," which appeared in the introduction to the Farmers Bulletin, No. 505, issued by the United States Department of Agriculture may however be quoted.

> The various benefits of good roads may be grouped under two main subdivisions, dealing, respectively, with economic benefits and social benefits. There is at present no unique or final measure of either the economic or the social benefits accruing to a community by the establishment of good public roads. So intimately are the public highways connected with every aspect of community life that almost any method devised to measure the benefits of good roads is incomplete.
>
> It is apparent, however, to anyone who has studied road matters for a period of years that the advantages of improved public roads have been repeatedly proved beyond all argument. There is no case on record where any community has ever regretted the improvement of its roads. It is doubtless true, however, that it is easy for good-roads advocates to underestimate the difficulties of bringing about a reform in the condition of roads.
>
> When the various ways in which good roads benefit a community are examined, a complex situation is found in which many actions and reactions take place. When good roads reduce the cost of hauling, adjacent land becomes more valuable; there is a corresponding tendency of population to increase, and, in its turn, this tendency

[1] See Chapter VI.

strengthens the demand for more good roads; social conditions improve; and the life of the community is influenced in numerous ways. It is not always correct to say that good roads are the primary cause of increase in property valuation. It is, however, proper to conclude that improved roads and an increased property valuation are inseparable.

For a number of years bituminous sand has been used in the construction of various types of pavements and wearing surfaces in the United States. The principal sources of commercial supplies of crude material at the present time, are in Kentucky, Oklahoma, and California.[1]

Of the many deposits in the United States and Europe with which the writer is familiar, the material from certain occurrences in California most closely resembles the bituminous sand of Alberta.[2]

Wearing surfaces for streets and highways must withstand constant heavy impact, change of temperature, and the action of sun and water. Cracking due to excessive hardness and insufficient plasticity, shoving due to instability, and deterioration and erosion due to absorption of water, are common sources of weakness. Cost of maintenance is of primary importance. Apart from considerations of comparative quality and utility, first cost of various materials do not vary greatly. Improper manipulation and use of unsuitable materials represent in America an annual loss of many millions of dollars.

Natural bituminous sand is a mechanical mixture of sand and bitumen, and it has frequently been found that there is little uniformity in such material. In the preparation of artificial mixtures, a more or less exact product may be had, the quality and percentages of aggregate and asphalt cement being readily controlled. Thus, a suitable mixture once established can be uniformly maintained. Assuming that in certain instances conditions will warrant the use of Alberta bituminous sand as a paving material, the necessary manipulation will present no serious difficulty.

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[1] Apart from the more important deposits of bituminous sand referred to in this report, other occurrences are found in Missouri, Arkansas, Utah, Wyoming, Oklahoma and Texas. Most of these deposits are relatively small, when compared with those in Alberta. Although the material from the various deposits in Canada and the United States is of the same general character, yet there are many sub-varieties, each of which requires different manipulation. For detailed reference to certain deposits in the United States, see Hilgard, E. W.: The Asphaltum Deposits of California, 1885. Wigglesworth, Trans. Am. Inst. Min. Engrs., 17, 115, 1888. Orton, Edward Occurrences of Petroleum, Natural Gas and Asphalt Rock, in Western Kentucky, Geol. Surv. of Ky., 1891. Parker, E. W.: Asphalt, U.S. Geol. Survey, Mineral Resources for 1889, 1890, 1891, 1892, 1893, 1894, 1895, 1896, 1897, 1898, 1899, 1900. Richardson, Clifford: Asphalt, U.S. Geol. Surv., Mineral Resources for 1893. Crawford, J. J.: 13th Annual Report California State Mining Bureau, 1896. Vaughan, T. W.: The Asphalt Deposits of Western Texas; U.S. Geol. Survey, Eighteenth Annual Report, pt. 5, pp. 930-935, 1897. Eldridge, G. H.: The Asphalt and Bituminous Rock Deposits of the U.S., U.S. Geol. Survey, 22nd Ann. Rep., pt. 1, pp. 209-452, 1901. Struthers, Joseph: Asphalt, U.S. Geol. Surv., Mineral Resources for 1901, 1902. Harper, H. W.: Univ. of Texas, Min. Surv. No. 3, May 1902. Eldrige, G. H.: Origin and Distribution of Asphalt and Bituminous Rock Deposits in the U.S. U.S. Geol. Surv., Bull. 213, pp. 296-305, 1903. Hayes, C. W.: Asphalt Deposits of Pike County, Ark., U.S. Geol. Surv., Bull. 213, pp. 353-355, 1903. Fairbanks, H. W.: U.S. Geol. Surv., Geol. Atlas, San Luis Folio, (No. 101), 1904. Taff, J. A.: Description of the Unleased Asphalt Lands in the Chickasaw Nation, Okla. U.S. Dept. Interior, Circ. 6, 14 pp., 1904. Boutwell, I. M.: Oil and Asphalt Properties in the Salt Lake Basin, Utah. U.S. Geol. Surv., Bull. 260, pp. 468-475, 1905. Havey, E. O.: Asphalt, U.S. Geol. Surv., Mineral Resources for 1903, 1904, 1905. Taff, J. A.: Asphalt, U.S. Geol. Surv., Mineral Resources for 1906, 1907, 1908. Branner, J. C. and Newsom, J. F. and Arnold, R.: U.S. Geol. Surv., Geol. Atlas, Santa Cruz, Folio (No. 163) 1909. Hutchinson, L. L.: Asphalt and Petroleum in Oklahoma, Okla. Geol. Surv., Bull. 2, 1911. Cramp, M. H.: Jour. Royal Soc. Arts, 1911. Peckham, S. F.: Weathering of Rock Asphalts of U.S. in Pavements, Trans. Am. Inst. of Chem. Eng. 5, 245, 1913. Snider, L. C.: Rock Asphalts of Oklahoma and their use in Paving; Okla. Geol. Surv., Circ. 5, 1913; "Oklahoma Rock Asphalts for paving," Jour. Soc. Chem. Ind., Vol. 34, 1915. Manufacturers' Record: Vol. 71, 1917. Northrup, J. D.: Asphalt, U.S. Geol. Surv., Mineral Resources for 1914, 1915, 1916, 1917. Abraham, Herbert: Asphalts and Allied Substances, New York, D. Van Nostrand Co., 1918. Miser, H. D. and Purdue, A. H.: Asphalt Deposits and Oil Conditions in Southwestern Arkansas, U.S. Geol. Surv. Bull. 691J., 1918. Osbon, C. C.: Asphalt and Allied Substances, U.S. Geol. Surv., Mineral Resources, 1920. Tillson, Geo. W.: "Street Pavement and Paving Materials," p. 264; The Mineral Industry, Vols. I-XXXIII. Rock Asphalts of Alabama and their use in Paving, Geol. Surv. of Alabama, 1925.

[2] Detailed reference to these deposits is omitted since they are fully described in Part I of the Twenty-Second Annual Report of the United States Geological Survey.

In the case of certain of the harder siliceous rock asphalts in the United States, serious difficulty has been met with in disintegrating the crude material. This difficulty would not be encountered in the manipulation of the comparatively soft Alberta bituminous sand. On the other hand unloading and stock piling of a material which rapidly resolidifies, presents a somewhat difficult problem.

Labour constitutes a costly element in the construction of asphalt wearing surfaces, and in Alberta probably amounts to from 25 to 35 per cent of the total cost of such work. Sheet asphalt and the various sand-rock mixes consist largely of filler, sand and crushed rock, each of which may usually be obtained in eastern Canada at moderate cost. In many parts of the Prairie Provinces, however, such aggregates are difficult to obtain—a condition which would favourably affect the demand for crude bituminous sand.

The extent to which bituminous sand has been used appears to be determined to some extent—but not altogether—by prevailing freight charges. Apart from this consideration, methods peculiar to the asphalt-paving industry itself should be borne in mind.

In many instances, bituminous sand has given satisfactory results when used as a paving material. Certain of the pavements constructed have been subjected merely to the comparatively light traffic of residential streets, while others have been tested under severe traffic conditions. On the other hand, a number of pavements surfaced with bituminous sand have proved unsatisfactory.

From a consideration of the successes and the failures which have resulted from the use of various bituminous sands and bituminous sandstones, the writer would in the strongest possible manner emphasize one conclusion: it is, that the most careful study should be given to its chemical, but more especially to its physical character, as a preliminary step, and that subsequently, the quality of the material used be systematically checked at frequent and regular intervals. To handle Alberta bituminous sand in a haphazard manner, either through failure to intelligently appreciate its true nature, or through lack of proper manipulation, will simply be to court failure and financial loss.

Two representative methods employed in the laying of bituminous sand wearing surfaces will be briefly referred to in the following pages.

City Street Improvement Company, San Francisco, California

During the interval between 1890 and 1916, the City Street Improvement Company[1] operated a bituminous sand quarry near Godola, California (Plate XXIII), but until 1910 paving operations by this company had been marked by many failures. In that year, Mr. J. R. Price, took charge of paving operations for the company, and, by introducing new methods, was entirely successful in demonstrating the merits of the bituminous sand. In 1913 in competition with oil asphalt (residuum) at $9[2] per ton, the

[1] J. R. Price, California Journal of Technology, August 1913.
In 1918 Messrs. Grant, Smith and Company of Portland, Oregon, acquired the quarries formerly operated by the City Street Improvement Company. A type of pavement introduced by this company consists of a 4-inch base of bituminous concrete under a 2-inch wearing surface of finely crushed rock and bituminous sand. It is claimed that, under the action of frost, this type of surface yields rather than fractures, subsequently settling again to its original position. It is claimed that the upkeep of this type of construction is low.

[2] Of this amount, probably $2.50 represented cost of barrelling.

product from the above quarry was shipped by rail to many points in California, the maximum rail haul being about 200 miles. When shipped by water, the radius of distribution was much greater. As a result of increased labour and transportation charges during the war, operations have subsequently been seriously curtailed.

The San Francisco paving plant of the City Street Improvement Company, (Plate XXIV), was equipped to handle either bituminous sand or oil asphalt mixes. When contract specifications permitted the optional use of bituminous sand or of oil asphalt, the company used bituminous sand.

At the Godola quarry, a descending section is as follows:—

Diatomaceous Monterey shale	30–70 feet.
Bituminous sand (16 to 18 per cent bitumen sol. in CS_2)	25 "
Diatomaceous Monterey shale	60 "
Bituminous sand (14 per cent bitumen sol. in CS_2)	32 "
Sandstone (1 to 2 per cent bitumen sol. in CS_2)	8 "
Bituminous sand (14 per cent bitumen sol. in CS_2)	8 "

The highest bed of bituminous sand has a somewhat fine mineral aggregate, and the associated bitumen has a penetration of 43° (Dow). The lowest beds have a coarse aggregate, the associated bitumen having a penetration of approximately 93° (Dow). The following are abridged analyses of representative samples:—

—	Highest bed	Lowest bed
	per cent	per cent
Bitumen	15·70	13·42
Mineral aggregate—		
Passing 200 mesh	8·86	4·02
Retained on 200 mesh	36·40	4·32
" 100 "	24·00	7·28
" 80 "	12·28	31·36
" 50 "	1·44	11·12
" 40 "	0·60	17·68
" 30 "	0·28	8·00
" 20 "	0·20	2·48
All passing 10 "	....	....

In order to secure a balanced mineral aggregate, the above classes of bituminous sand were combined in the proportion of one of fine-grained to three of coarse-grained. The penetration of bitumen in the resulting mixture was approximately 80° (Dow). In order to correct still further the grading of the sand aggregate, stone dust and clean sand were added. A typical charge as introduced into the mixer was as follows:—

—	Pounds	Per cent of mix
Fine-grained bituminous sand	1,200	78·43
Coarse- " "	3,600	
Stone dust	690	11·0
Clean sand	630	10·3
Total charge (for wagon load)	6,120	

PLATE XXIV

General view of bituminous sand paving plant equipped with two torpedo mixers, City Street Improvement Company, San Francisco, Cal.

PLATE XXV

Bituminous sand heating and mixing plant (railroad type). Capacity per 8 hours is 150 tons bituminous sand. Designs for adapting this type of mixer so that it can be mounted on motor truck, were prepared in 1920.

PLATE XXVI

Battery of torpedo mixers for manipulation of bituminous sand, having capacity of 70 tons per ten hours.

PLATE XXVII

Torpedo mixer in course of erection (semi-portable type).

As an indication of the character of mixture produced in the above manner, an abridged analysis of material as actually laid by the City Street Improvement Company is given in A. In B for purposes of comparison, is given a satisfactory combination of bitumen and mineral aggregate for a standard sheet asphalt pavement laid under similar climatic conditions. In Alberta the percentage of bitumen in a sheet asphalt surface would be approximately 11·5 per cent.

—	A	B
Bitumen soluble in CS_2	10·3	10·5
Mineral aggregate—		
Stone dust passing 200 mesh	13·6	13·0
Sand passing 80 and retained on 200 mesh	26·5	26·0
" 50 " 80 "	24·3	23·5
" 30 " 50 "	17·4	19·0
" 20 " 30 "	5·0	5·0
" 10 " 20 "	2·9	3·0

The bituminous sand as mined near Godola is shipped to the point at which it is to be laid. In order to properly incorporate such sand and stone aggregate as may be added, and to thoroughly mix the two grades of bituminous sand, the bituminous sand must be completely disintegrated. This is accomplished by the use of a torpedo mixer[1], (see Plates XXIV-XXX), consisting of a conical-shaped drum revolving at a speed of 12 to 14 revolutions per minute, and placed above a firebox. The inside face of the drum is fitted with a series of lifters and with a spiral baffle extending from end to end. In California, the time required to heat and discharge a batch of bituminous sand and added aggregate does not exceed 15 minutes. The motion of the drum is reversible, and material, when heated, may be discharged or thrown back upon itself.

In an article prepared for the California Journal of Technology in 1913 by Mr. J. R. Price, the following comment is made,—

The proponents of Santa Cruz (Godola) bituminous sand rock have no apology to offer on its behalf. If it does not give good service, it is entirely due to ignorance of the methods of properly laying it. Not one single failure has been noted with this paving material since its preparation as herein described. It is simply a question of handling the material which nature has prepared in an intelligent manner. Pavements laid with this material, if undisturbed by cutting and trenching, will last for half a century without appreciable expense for repairs. It is at all times a smooth, dustless pavement, capable of withstanding the wear of traffic, or the ravages of time. This is not an imaginary picture. The material that has been subjected to traffic for 27 years, still has the same percentage of natural asphalt it contained when laid on the roadway. . . .

At various times during the past few years the adaptability of bituminous sand as a paving material has been adversely criticized. The following expressions of opinion by engineers who are familiar with this class of material, are therefore of interest. Other letters which the writer has received from city engineers and street superintendents, confirm statements made in the letters quoted below.

[1] In operation (1916) at various paving plants of: City Street Improvement Co., Cal., and of Mellon Construction Co., Salt Lake City, Utah.

(Letter No. 1)

Your inquiry as to our experience in the use of bituminous sandstones has been received and given careful attention. The sandstone used in Oakland is all from the Santa Cruz quarries operated by the City Street Improvement Company of San Francisco. Oakland used the material in its natural state intermittently for some fifteen years with varying results. Its use was abandoned in 1907, but resumed in 1911 in a different form. Since 1911 we have used this material in the construction of about one and one-half miles of street with uniformly satisfactory results. However, the material is not used in its natural form, but modified by the addition of suitable sand and stone dust to produce a mixture conforming closely to the ideal composition of a standard asphalt pavement.

The first street constructed with this material in Oakland was built about twenty-two years ago and is in excellent condition to-day. This street has had a steady stream of light traffic, but is not a portion of a thoroughfare. Another street laid in 1898 has carried a reasonably heavy traffic from the time of its construction, and is now one of our main business streets. The pavement on this street had no repairs until last year, when about two and one-half per cent of the surface was renewed. Additional repairs are now being made to about the same amount. Other streets have given equally good service, while still others have been a failure from the time of their construction. This variation in service leads us to believe that the material is capable of making a satisfactory street surface, and that faulty manipulation is responsible for the failures. Investigation along these lines has shown that where the material has failed its composition corresponds very closely to that of reported failures of other asphaltic material in other cities; that is the mesh composition or the bituminous content is unbalanced. Pavements that have given us good service have shown a fairly balanced mixture. It appears that the product as mined does not have the proper composition and comes in several grades. We believe that we have overcome these difficulties by mixing two grades of sandstone, modifying the mixture by the addition of sand and stone dust, and analysing the product from day to day, to enable us to make further modifications as may seem necessary. It is the general opinion of inspectors and others who observe the product that appears on the street from day to day that the resulting pavement is even better than that obtained with the artificial mixture of California asphalt, sand and stone dust. It seems to be more adhesive, tougher and more dense. Pending a more definite determination of these claims, I am not prepared to give the material any preference over the ordinary artificial mixture, but I do believe that it is as good.

Our experience in Oakland with bituminous sandstones is limited to this particular product. Other sandstones may not give good service from the nature of their composition or through lack of proper manipulation. It has taken many years to discover the proper method of using this particular sandstone. In view of the advance in knowledge of asphaltic materials in the past few years it should not take so long to discover the value of a new field opened at this date. However, the first work done with material from a new field should be in small quantities until the value of the product is determined by trial and the proper method of manipulation is developed. I might suggest that failures in the early work might be due as much to the method of manipulation as to the character of the material.

(Signed) WALTER N. FRICKSTAD,
Asst. Supt. of Streets,
Oakland, Cal.

Approved:—
(Signed) Percy F. Brown,
Superintendent of Streets, and
Ex-officio City Engr.

Feby. 2, 1914.

(Letter No. 2)

In reply to your letter of January 24, 1914, regarding bituminous rock pavements laid in San Francisco, will say that I find them to be very satisfactory. We have some streets of this material that have been down many years which are still in an excellent condition.

It must be understood, however, that the natural bituminous rock cannot be handled in a haphazard manner. The material is seldom mined in a condition that is suitable for paving purposes, and in such cases where the run of the mine has been laid on the street, the resulting pavements have been of service only in those sections where the traffic is very light. In instances where the rock has been subjected to heavy duty and has survived for many years, it has been found by inspection that some selection of rock has been exercised or an after treatment used, which, in either case, provided a mixture approaching the recognized standard in asphalt paving practice.

On this account the present method of handling the bituminous rock is vastly different from that prevailing several years ago. The rock from the different strata of the mine is now selected and shipped so that a proper grading of materials can be made at the mixing plant. The resulting product is now one that is remarkable for its uniformity, and all the pavements that have been laid under this system, during the last four years, promise to give as good service as the original ones they are patterned after.

(Signed) M. M. O'SHAUGHNESSY,
City Engineer, San Francisco, Cal.

San Francisco, Jan. 30, 1914.

(Letter No. 3)

In answer to your communication relative to the bituminous deposits in the vicinity of Santa Barbara, would say that in my opinion an excellent pavement can be made from this material if it is properly treated.

The material here consists of some beach and some bank sand, a rather soft lime rock and sea shells composing the coarse aggregate, and all being bonded together with an asphaltic base bitumen. The sand and asphalt vary greatly in quantity even with each batch, consequently each batch requires special treatment. Some of the bitumen will contain more light oils than others and require longer heating than do those containing a less amount of the light oils. The grading of the sand, too, is always different one batch from another, so to successfully use the material from the natural bituminous deposits for the construction of a good pavement requires considerable study and experience.

In the year 1888 this city laid about two miles of pavement made from the natural bitumen. This pavement did not wear well in places, due, undoubtedly, to careless treatment and preparation; though in other places it wore well. In 1898 about one-half of this pavement was removed and replaced with a refined sheet asphalt pavement. The pavement that was not removed is still in use, and most of it is in very good condition.

In short, I would say that, from my observation and experience, I believe, with proper treatment, as good a pavement can be made with the material from natural deposits of bituminous lime rock or sandstone as can be laid with the use of refined asphalt.

(Signed) ELDON A. GARLAND,
City Engineer, Santa Barbara, Cal.

Santa Barbara, Feby. 11, 1914.

The bituminous rock used in San Francisco and in Oakland is from quarries near Santa Cruz.

In his book entitled "Street Pavements and Paving Materials" Mr. Geo. W. Tillson, Consulting Engineer to the Borough President, Borough of Brooklyn, City of New York, states:—

Some bituminous limestone has been found in this country (United States) as well as a sandstone bearing asphalt, and also in California beds of sand which contained asphalt, and of which many of the early California pavements were made. These pavements were laid in a very crude manner, with but little knowledge of the material or of the subject, and a great many of them failed in a short time, as might have been

expected. These failures, however, should not have been charged up to California asphalt or to asphalt pavements, as experience has demonstrated that with the proper treatment, a good pavement can be laid with this material.

As an illustration of the necessity of proper manipulation, an interurban road with which the writer is familiar, between Santa Barbara and Carpinteria, may be mentioned. This road is subjected to varied traffic conditions, including a large volume of fast automobile travel, and trucks. No wide tire ordinance is in force.

Different sections of this road were laid by different contractors and, although practically the same bituminous sand was used throughout, the contrast between the various sections of the completed work when examined by the writer in 1914 was marked. Thus where the bituminous sand had not been heated sufficiently to drive off the lighter oils, the surface was rutted. Where the material had been overheated the surface was very hard and showed considerable evidence of flaking. Where the material had been properly handled the results appeared to be excellent.

As an indication of the success that has attended the use of bituminous sandstone in Oklahoma, the following letter, received by the writer, is of interest.

LAWTON, OKLAHOMA.

In reply to your favor of Jan. 22 will say that in 1908-9 this city laid three miles of bituminous rock pavement consisting of a base of material containing from 5 to 7 per cent bitumen, broken to pass through a 3-inch screen, spread and rolled to a thickness of four inches. Upon this was spread a wearing surface of material, containing from 9 to 12 per cent bitumen, ground fine and heated sufficiently for perfect adhesion under the roller. The wearing surface is two inches in thickness.

This pavement has now been in use five years and the repairs necessary have not been as much as one tenth of one percent. It is smooth, easy to clean and the heat of summer does not soften it to the degree that it does sheet asphalt.

The satisfaction with this pavement was such that four additional miles have since been laid and there is no fault to be found with any of it.

No protection has been afforded this pavement at any time and trenching machines, traction engines and house movers have used it freely without damage.

The cost of the first contract was $1.85 and the last $1.69 per square yard.

The success of Ardmore, Okla., with this material was the reason for its use here. Tulsa, Okla., also has several miles and the City Engineer states that in his opinion it is the best pavement in the city.

I think the Ardmore and Tulsa pavement has a concrete base but the rock asphalt base laid here has met all requirements.

When first laid this pavement cuts under traffic but soon irons out smooth and seems to get better with time.

Am not prepared to say what it would do under very heavy traffic but for cities up to 10,000 population and for resident streets everywhere I regard it as the ideal pavement.

Any additional information will be gladly furnished.

Yours very truly,
FRANK B. KING
City Engineer

The following general reference to the use of bituminous rock occurs in Mineral Resources of the United States, 1918, Part II:—

Bituminous rock, a variety of native asphalt, is used in the construction of city streets and country highways. Most of the pavements in the United States have heretofore been made with imported native asphalt and petroleum asphalt, but this country contains vast quantities of bituminous rock that could economically be used

for paving, and this would release a large quantity of oil suitable for fuel. European countries use large quantities of bituminous rock in road construction, and many good pavements have been made with it in the United States.

The following data, explaining the use of bituminous rock in road construction, were contributed in substance by James S. Downard, of Sulphur, Oklahoma.

There are two methods of using bituminous rock in paving. According to one, the rock is powdered, heated, spread about two inches thick on a concrete foundation, and compressed by a steam roller. According to the other, the bituminous rock is crushed and used in macadamizing.

The advantages of a bituminous rock pavement are based upon its origin and composition. It is a limestone or sandstone saturated by nature with asphalt, the temper of which is of secondary importance in paving construction. Properly constructed, bituminous rock pavements contain a high percentage of filler and no excess asphalt, and therefore are attractive, permanent, and waterproof, and do not creep.

Although good bituminous rock pavements have been laid in Kansas City, Kan., Oklahoma City, Okla., and other cities, many rock asphalt pavements constructed in the United States have been experimental, and have not been successful because of the failure of the contractor to understand the nature of rock asphalt. Bituminous rock varies in quality, and each deposit must be analysed and treated individually. One of the best known specifications is a mixture of 40 per cent bituminous limestone and 60 per cent bituminous sandstone. One half of the bituminous sandstone should be ground finely and the remainder coarsely. Bituminous rock pavements are used in Kansas City, Kan.; Salt Lake City, Utah; San Francisco, Cal.; Ardmore, Ada, Norman, Houldenville, Pawhuska, Durant, Lawton and Oklahoma City, Okla.; and Dallas, Bonham, Paris, Sherman, Mount Pleasant, San Antonio, Houston, and Beaumont, Tex. Some bituminous rock pavements in Kansas City have been continuously and successfully used by heavy traffic for 20 years.

At the present time (April, 1925), the Draper Manufacturing Company at their plant at Petrolia, Ont., is completing a machine for heating and mixing crude bituminous sand for paving purposes. It is stated that this heated mixer will be available for service during the coming season.

Kentucky Rock Asphalt Company, Louisville, Ky.

For more than 30 years[1] bituminous sandstone has been mined in Kentucky and used in the surfacing of streets and highways. At various times the Breckenridge Asphalt Company, Silician Asphalt Company, Green River Asphalt Company, Standard Asphalt Company, Wadsworth Stone and Paving Company, and others have carried on operations on a somewhat small scale, but since 1916 the Kentucky Rock Asphalt Company has been principal producer.[2] (Plate XXIX.)

The bed of bituminous sand is not uniform throughout its thickness, either as regards percentage of associated bitumen or grading of mineral aggregate. As in California, however, by combining material for two strata, a satisfactory product is obtained. Laboratory examination of all material quarried, and of the final product, ensures uniformity.

The company undertakes that the rock asphalt shall contain not less than 6·5 per cent nor more than 7·5 per cent of bitumen as determined by the standard ignition method upon a dried sample. The bitumen when determined by extraction with cold carbon bisulphide shall be from 85

[1] The first wearing surfaces laid with Kentucky bituminous sandstone were completed in Nashville, Tennessee, and in Louisville, Kentucky, during the years 1888 and 1889. This material came from the Green River deposits, which are now known as the Kyrock formations. Portions of these streets in Nashville, Tennessee, are still in serviceable condition without any repairs, as verified by letter from W. W. Southgate, City Engineer, Nashville, Tennessee. In 1890 many streets were completed in Buffalo, New York, quite a few of which are still in service.

[2] Reference to quarrying operations of this company will be found on page 161, in Chapter IV.

to 95 per cent of the bitumen content as determined by the standard ignition method, and shall have the following properties:—

Specific gravity at 25° C/25° C not less than 1·01 nor more than 1·025.
Float Test at 122° F. not less than 75 seconds nor more than 175 seconds.
The mineral aggregate of the rock asphalt shall contain not less than 94 per cent of silica, and shall have a grading within the following limits:

Passing 200 mesh	5 to 12 per cent
Passing 80 mesh and retained on 200 mesh	12 to 25 "
Passing 40 mesh and retained on 80 mesh	40 to 65 "
Passing 10 mesh and retained on 40 mesh	5 to 20 "
Retained on 10 mesh not more than 10 per cent.	

Kentucky bituminous sandstone[1] is laid cold, and the material as sold by the company, requires no further manipulation or modification. This obviates the necessity of a special plant and equipment for heating and mixing—a distinct advantage on rural roads, and at points removed from centres of population. Since the material is practically weatherproof, it can be shipped in open cars, and stored along highways, without danger of deterioration.

Kentucky bituminous sandstone is successfully laid on concrete, macadam, slag, chert and modified Telford bases. It is also used extensively for re-surfacing of the foregoing types of construction and worn-out brick pavements—a practice which is becoming more and more general.[2] Thickness of compacted wearing surfaces rarely exceeds 1¼ inch.

In analysing cost of standard types of hot mixes for wearing surfaces, and omitting overhead, interest, depreciation and labour costs, conclusions arrived at are frequently unfavourable to the use of 7 per cent bituminous sandstone.[3] At most plants, however, these items represent a considerable portion of total cost. Thus in one instance, plant superintendent and plant foreman contended that their costs for sheet asphalt mixes did not exceed $4 per ton, whereas a study of their books, indicated that actual costs aggregated not less than $14.88 per ton.

It is stated that during 1923 contractors using Kentucky bituminous sandstone and operating in 26 different States, laid a total of about 2½ million yards of wearing surface. The maximum rail haul exceeded 1,000 miles. The use of this material appears to have given general satisfaction, a statement which is borne out by the following letters:—

[1] Detailed reference to the methods adopted in the use of this material will be found in literature issued by the Kentucky Rock Asphalt Company, Marion E. Taylor Bldg., Louisville, Ky., U.S.A.

[2] Salvaging Old Pavements by Re-surfacing with Asphalt. Brochure No. 14. Also see "How Schenectady Salvaged its Pavements," Circular No. 7. The Asphalt Association, New York. U.S. Patent 938698. J. A. W. Pine (1909).

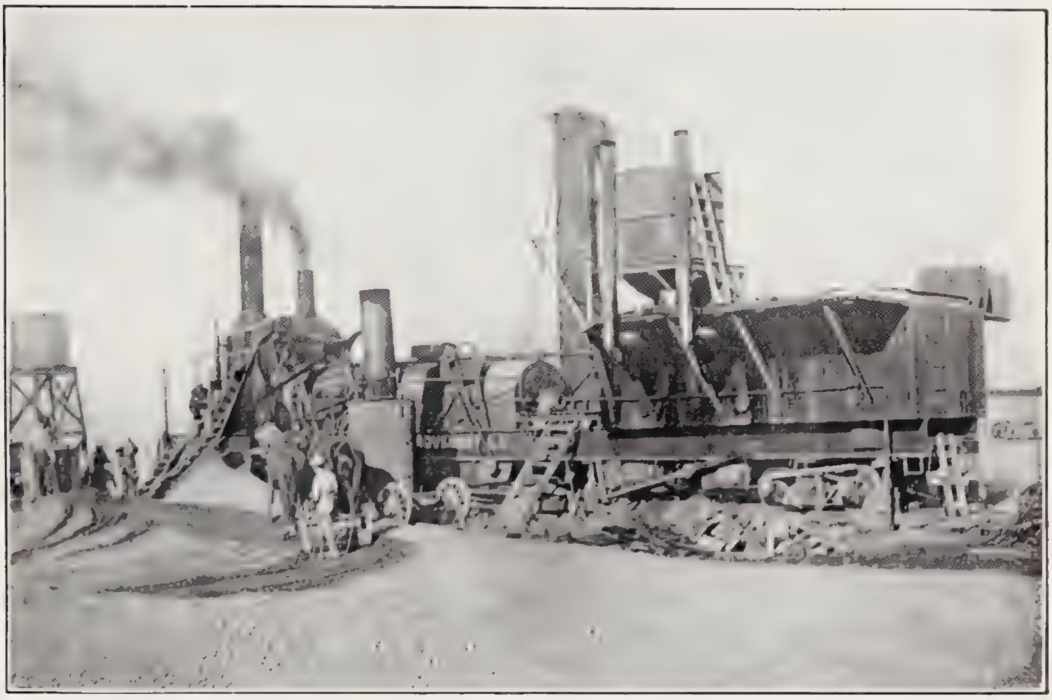
[3] Cost of Bituminous sand delivered at Rutland, Vt. (1925):—

Cost of bituminous sand at mine	$9 50 per ton
Freight to Rutland, Vt. (approx. 1,070 miles)	6 50 "
Unloading cost	0 25 "
Hauling cost	0 40 "
Application	1 00 "
Total cost in place	$17 65 "
or per square yard, 1½-inch wearing surface	1 19

Port Huron, Michigan, has recently (March 1925) placed an order for Kentucky bituminous sand (rock asphalt) at the following prices:—

Cost of material (f.o.b. Bowling Green, Ky.)	$12 00 per ton
Freight Bowling Green–Port Huron (approx. 555 miles)	4 65 "
Total cost f.o.b. Port Huron	$16 65 "

Much of the above bituminous sandstone is being used for repair work, for which cold rolled material has obvious advantages.



Type of railroad paving plant for heating and mixing bituminous sand, City Street Improvement Company.

Bituminous sandstone quarry operated by Kentucky Rock Asphalt Company, at Kyrock, Ky. Crushing plant is shown in the upper right hand corner.

PLATE XXX

Heated mixer operated by Uvalde Rock Asphalt Co., San Antonio, Texas.

PLATE XXXI

Electrically operated Bucyrus dragline, equipped with 125-foot boom and a 4-yard bucket, engaging in stripping overburden.

. . . For a long time I was afraid to use Kentucky rock asphalt for paving purposes because the material as shipped from the mines was not uniform in consistency; in fact, was very erratic and unreliable. However, within the last few years the Kentucky Rock Asphalt Co. has been handling their material with scientific precision by a method of blending fat and lean Kentucky rock and thoroughly pulverizing the material during this process. The result is a very reliable material, about the only draw-back being that when the pavement is first laid it scars pretty badly from the toes and heels of horseshoes and steel tires of animal-drawn traffic. However, these scars are soon ironed out under traffic and are completely obliterated, and within from 3 to 6 months' time the pavement has cured satisfactorily and remains permanent.

This city has within the last 2 years laid upward of one hundred and fifty thousand square yards of Kentucky rock asphalt on a well-compacted macadam base with the surface of the macadam left with somewhat open interstices into which the asphalt anchors and holds fast. The pavement affords a very gritty surface and is not slippery at all. We have laid it on 10 per cent grades with satisfactory results. The pavement here so far has been entirely satisfactory and is quite popular with our abutting property tax payers.

W. W. SOUTHGATE,
City Engineer, City of Nashville, Tenn.

Replying to your letter of December 3rd, 1924, in reference to my experience with Kentucky Rock Asphalt for paving construction will say that Jefferson county, Kentucky, has about nineteen miles of Kentucky rock asphalt part of which was constructed in 1915 and 1916 and the remainder in 1921.

The paving has given entire satisfaction, in fact at one time during the construction and use of Camp Knox it carried at least four thousand vehicles a day including artillery and trucks.

The surface was upon an old macadam base from about nine to twelve inches in thickness and the road is in first class condition to-day.

The maintenance cost has not been over $100 per mile per year.

(Signed) MERRITT DRANE,
County Road Engineer,
Jefferson County, Kentucky.

LOUISVILLE, December 3rd, 1924.

Uvalde Rock Asphalt Company, San Antonio, Texas[1]

Although the product of the above company is a bituminous limestone, nevertheless the extent and success of operations is worthy of reference in considering the general use of natural rock asphalt in the construction of wearing surfaces. As in California, Kentucky, and other States, early attempts to utilize the material were in some instances marred by failure and disappointment. An outstanding obstacle was presented by prohibitive freight rates, which restricted shipments to nearby points. Only during recent years, have freight adjustments permitted wide distribution of the Uvalde product.

The quarries[2] operated by the Uvalde Rock Asphalt Company, (Plates XXXIX, XL) are situated about 7 miles south of Cline, Texas, a station 110 miles west of San Antonio on the Southern Pacific railway. Laboratory tests[3] of a sample of the bituminous limestone quarried showed the following results:—

[1] Reference to operations will be found in literature issued by the company; see also "Rock Products," November 3, 1923; "Explosives Engineer," February, 1924, and "The Excavating Engineer," August, 1924. Univ of Texas Bull. No. 1839; July 10, 1918.
[2] For reference to mining operations by this company, see page 162, Chapter IV.
[3] Determinations by Office of Public Roads, U.S. Dept. of Agriculture, 1913.

Report on Rock Asphalt

Sample Nos. 6511-12-13.

Specific gravity..	2·103
Bitumen soluble in CS_2..	14·000 per cent
Character of recovered bitumen..	Very hard
Brittle glossy..	
Semi-solid..	
Specific gravity of recovered bitumen..	1·082
Melting-point of recovered bitumen..	90·2° C. 195° F.
Penetration 100 grm. 5 sec. 25° C. (77° F.)..	0·8 mm.
Per cent bituminous insol. in 86° Bé paraffin naphtha.	48·26
Per cent fixed carbon..	15·93
Per cent ash..	1·47

Shell limestone aggregate impregnated with bitumen. The classification was made from the general appearance of the rock. Nos. 6,511 and 6,512 both showed bitumen in small shell pockets, but No. 6,513 did not.

In criticism of the Uvalde rock lack of uniformity has been claimed. It appears, however, that the material is quite as uniform as that produced from European deposits. Selection is based on high, medium or low bitumen content, in accordance with anticipated traffic conditions.

The above material is laid either hot or cold, the relative proportions of each type of pavement being indicated by the following tables:—

Cold Rolled

Years.	Square Yards.	Years.	Square Yards.
1914..........................	7,386	1919..........................	371,139
1915..........................	....	1920..........................	891,830
1916..........................	....	1921..........................	1,125,436
1917..........................	105,981	1922..........................	806,832
1918..........................	80,000	Total..................	3,389,604

Hot Mix

Years.	Square Yards.	Years.	Square Yards.
1911..........................	1,500	1918..........................	268,198
1912..........................	20,608	1919..........................	73,388
1913..........................	63,898	1920..........................	155,006
1914..........................	107,555	1921..........................	512,230
1915..........................	112,660	1922..........................	629,514
1916..........................	199,319		
1917..........................	146,019	Total..................	2,289,967

The rock is crushed at the quarry to a size approximating a 10-inch ring and shipped to localities where required. It is then passed through a pulverizer, which further reduces it to pieces not larger than half an inch.

For the hot mixture, the material is heated in a revolving drum. (Figures 4 and 5, Plate XXX) with the addition of a sufficient paraffin base oil to soften the bitumen to the required penetration. The resulting mixture

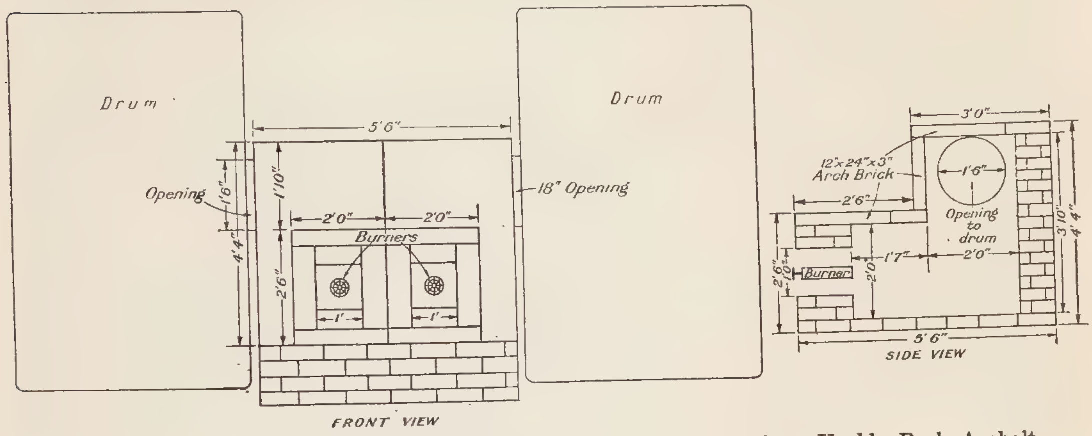


Fig. 4.—Typical flame and combustion chamber used with drum mixer, Uvalde Rock Asphalt Company.

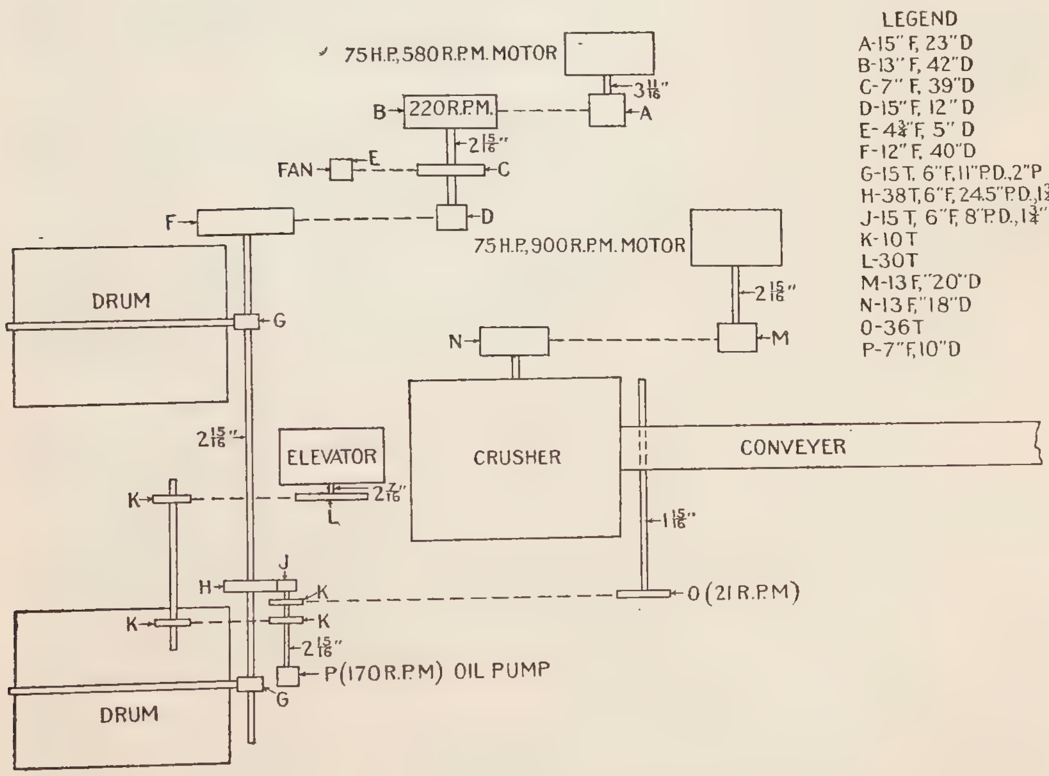


Fig. 5.—General arrangement of typical two-drum heating and mixing plant, Uvalde Rock Asphalt Company.

is then spread to the desired thickness and rolled and cross-rolled until ultimate compression is obtained. Four hours after rolling, the hot mix surface may be opened to traffic.

In laying cold mixtures, a similar method is employed, with the difference that an asphaltic base oil is used for fluxing. Apart from overhead and fixed charges, the cost (1925) per ton of crushing, mixing and laying Uvalde rock asphalt is approximately as follows: unloading, $0.15; crushing and mixing, $0.50; haulage, $0.50; labour for laying $0.40; flux oil, $0.25; total $1.80.

Comment by responsible engineers and others indicates that results obtained by the Uvalde Rock Asphalt Company are entirely satisfactory.

During the past thirty years, James S. Downard and associates have constructed in Oklahoma and Texas many miles of wearing surface in which bituminous sand, bituminous limestone, or a mixture of the two has been used successfully. In competition with $20 oil asphalt, the maximum rail haul has exceeded 400 miles. Materials used are heated in a simple type of mixer (Figure 6) designed by Mr. Downard. It is stated that, when heating and mixing bituminous rock quarried in Oklahoma, the capacity of the mixer is 2,000-2,500 square yards of 2-inch compacted wearing surface per 10 hours, with operating costs of approximately $70. Capacity and operating cost for heating and mixing Alberta bituminous sand can only be determined by actual demonstration.

Blue-prints illustrating construction of the above mixer, together with bill of materials[1], were submitted to a foundry which estimated the cost of constructing such a mixer at approximately $5,000, and the total weight at approximately 12 tons.

The possibility of laying Alberta bituminous sand cold has not yet been considered. In this connexion, however, the following comment by Chas. A. Mullen[2], Director of Paving Dept., Milton Hersey Co., Ltd., Montreal, on the Amiesite pavement, is of interest.

> The Amiesite pavement consists of a surface layer of mixed method bituminous macadam, but it also may consist of any other type of mineral aggregate treated in the Amiesite way.
>
> The differentiating feature is that the mixture is made at a central manufacturing plant and shipped to the job, where it is laid cold, the bituminous cement being kept plastic through the use of a light oil such as kerosene, called the "liquifier."
>
> Amiesite is laid cold, days and weeks or even months and years after its manufacture. As long as the mixture remains piled in bulk, the "liquifier" mostly remains in it; yet, when spread upon a foundation and rolled, exposed in a thin layer to the atmosphere, the "liquifier" evaporates and the bituminous cement is thereby gradually hardened to the desired consistency. Amiesite was first laid in Canada last year, principally at Quebec city; but it has been laid quite extensively and for a number of years past around Philadelphia, the home of Dr. Amies, its inventor.
>
> The Amiesite mixture is made by first introducing cold mineral aggregate into the mixer, then dampening it thoroughly with a light oil like kerosene, called the "liquifier," as a sort of priming coat and temporary flux, then coating the dampened mineral aggregate with liquid asphalt cement of the desired consistency, after which a proportion of hydrated lime is added.
>
> The mixed asphalt macadam type of pavement construction is that to which the Amiesite method has been successfully applied. An under layer of coarse Amiesite mixture in which the mineral aggregate is principally one and one-half to three-eighths-inch stone is first spread and compressed upon the prepared foundation, then an upper layer of fine "Amiesite" mixture in which the mineral aggregate is principally three-eighths to one-eighth inch stone chips is spread and compressed thereupon.

---

[1] The bill of materials used in the construction of the above mixer may be obtained on application to the writer.

[2] Engineering Journal, January, 1925—p. 17.

The bitumen-coated particles of the fine Amiesite upper course mixture are of a size to key into the surface voids of the bitumen-coated particles of the compressed coarse Amiesite under course mixture on the macadam principle; which is facilitated by the fact that the bitumen coating of the under course remains plastic while this is being done. When the rolling is completed, sand is spread evenly over the surface of the pavement to fill the small surface voids which still remain in the upper course and seal it further as it receives its final compression under traffic.

The cold laying feature of Amiesite, combined with the macadam construction, seems to gain for it whatever advantage there is in the special non-rolling and lightly rolling features of the Warrenite-Bitulithic and the Standardite pavements; and the rolling of the two Amiesite courses together while they are both still plastic is done at leisure instead of against the rapid cooling of the mixtures depending upon heat for the plasticity during laying and compressing. Amiesite is also " densest at its top.

It was suggested to the writer by Mr. Mullen, that the broad principle of the " Amiesite " process could be employed in order to utilize the Alberta bituminous sands to supply the bitumen and the fine aggregate in conjunction with local coarse aggregate for making asphaltic concrete mixtures at air temperature, by first covering the surface and filling the surface pores of the coarse aggregate with a light volatile mineral oil, such as kerosene, to act as a solvent and temporary flux to the bitumen of the bituminous sand next to be applied.

Mr. Mullen pointed out that some of the bituminous sand carries sufficient bitumen to spare enough for coating the local coarse aggregate, and that the above mixture could undoubtedly be made at air temperature in an ordinary concrete mixer, using the tank for kerosene to wet the coarse aggregate before introducing the bituminous sand, instead of for water as when preparing a hydraulic concrete mixture.

A light volatile mineral oil such as kerosene could also be mixed with the bituminous sand before shipping or storing, so that the bitumen thereof would be softened to the desired consistency for handling and laying. Once the material is spread out in a thin layer, such light oil will quickly volatilize and the material will harden.

(2) For Surfacing of Sidewalks,[1] *Railway Platforms, Architectural Construction, Etc.*

Bituminous sand combined with clean sand, or with clean sand and crushed rock aggregates.

In European cities, bituminous materials have been used extensively for many years in the construction of sidewalks (footways). In Paris alone, the length of such walks (trottoirs) exceeds 1,800 miles.

Such a type of walk is agreeable to the foot, and gives more secure footing than cement or granite flags.

Sidewalks constructed largely of bituminous sand are not uncommon in the United States, and, when properly designed, have given excellent results under heavy traffic and severe climatic conditions. A specification which has given satisfactory results in the United States, may be summarized as follows:—

Base. 4 inches of crushed limestone, or other suitable rock, all of which passes a $1\frac{1}{2}$-inch ring, and is retained on a $\frac{3}{4}$-inch screen. Compact by means of 300-pound hand-roller.

[1] Rosengarten, Walter E.: "The Characteristics of Asphalt Sidewalks."

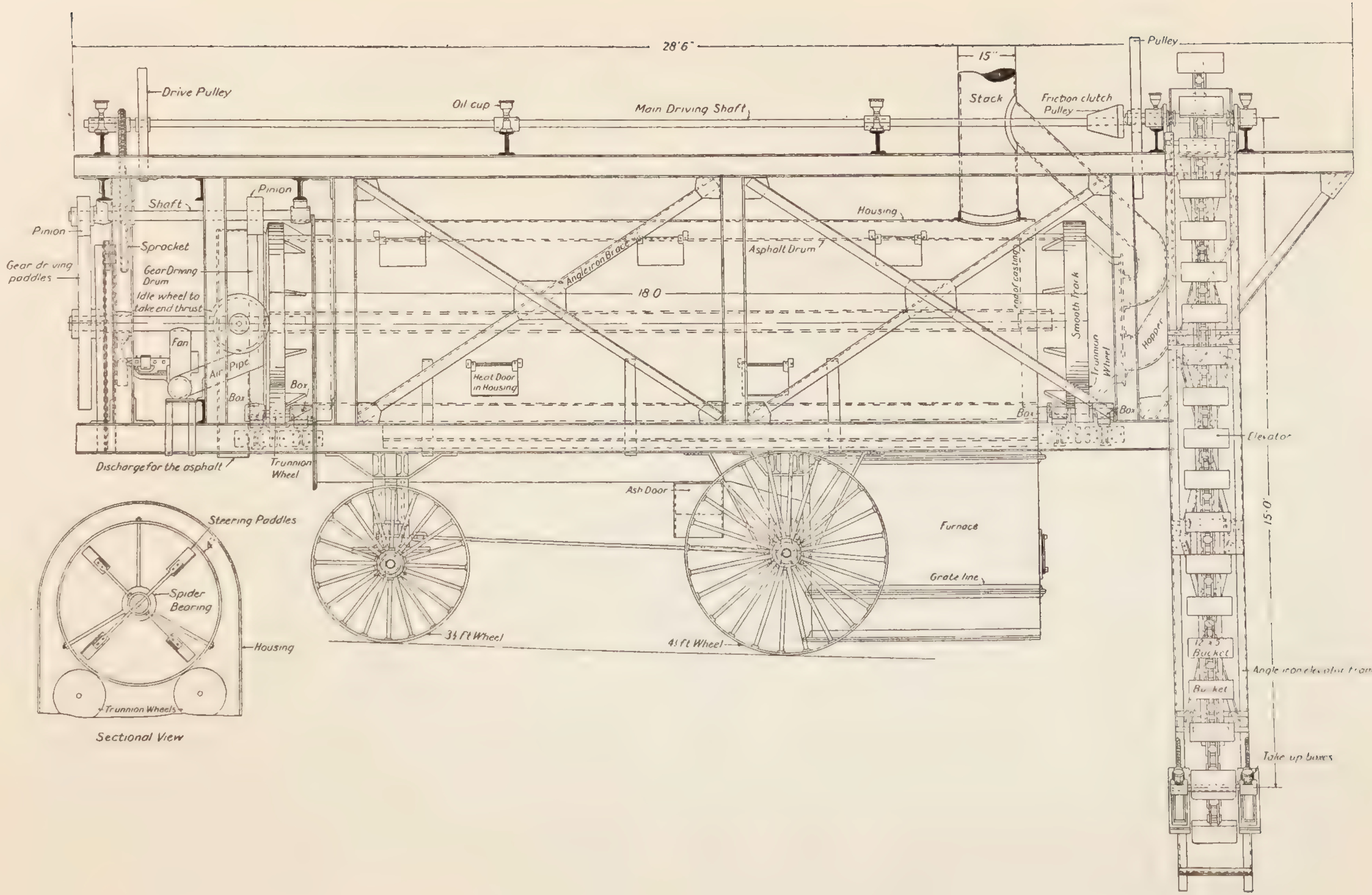


Fig. 6.—Downard standard rock asphalt heater and mixer.

Wearing Surface. (1½-inch compacted). A satisfactory mixture may be had by combining 100 pounds of 14 per cent bituminous sand with 50 to 60 pounds of crushed rock, preferably limestone. The crushed rock should pass a ¼-inch ring, and be retained on a 10-mesh screen. Dust should be avoided, as it absorbs too much bitumen.

Curb. Wooden headers, such as tamarac or fir, secured to stakes, will give satisfactory results, if permanent stone-curbs are not available.

One mile of sidewalk, 5 feet wide and having a 1½-inch compacted surface, will require approximately 135 tons of bituminous sand.

In 1915, in collaboration with the late Mr. John Doctor,[1] the writer prepared a number of apparently satisfactory experimental blocks, suitable for sidewalk construction, by combining crushed gravel with bituminous sand. At that time no actual construction was undertaken, but, during the fall of 1922, the city of Edmonton, Alberta, constructed approximately 960 square yards of sidewalk surfacing, using bituminous sand. This work was carried out under the supervision of Mr. A. W. Haddow, City Engineer, who reports that this surface has proved very satisfactory from the pedestrian's viewpoint. The following reference by Mr. Haddow, to the above class of construction, summarizes the procedure adopted.

Previous to 1922 the City of Edmonton found it necessary to construct a large mileage of cinder walks. These were constructed by placing 2 x 4 runners along each side of the walk, and filling in with cinders. It soon became evident, however, that the cinder walk would be too dusty and that some form of "top-dressing" must be used. The suggestion was made that bituminous sands be used as a top dressing for cinder walks and arrangements were made with Mr. Draper of the McMurray Asphaltum and Oil Ltd., to ship a car to Edmonton. Later a second car was received.

Both cars were carefully sampled and from the analysis a mixture was set, that would approach a standard sheet asphalt grading. The best combination for the first car was, 100 parts by weight of bituminous sand, 50 parts by weight of coarse sand, and 10 parts by weight of Portland cement. The second car varied somewhat from the first in percentage of bitumen and grading of the mineral aggregate.

The bituminous sands were charged into the drum of a Grand Rapids Hot Mixer together with the coarse local sand and Portland cement, a charge being made up of 800 pounds of bituminous sand, 400 pounds of coarse local sand and 80 pounds of Portland cement. Each charge was held in the mixer for a period varying from 35 up to 65 minutes at a temperature of 300° F. The charge was then loaded into a dump wagon and when three charges were ready the load was hauled to the street and laid in the ordinary way. The rolling was done with a water-filled hand roller weighing approximately 600 pounds.

In preparing the cinder sub-grade the loose cinders were removed to depth of 1½ inches and then brought to a uniform surface by rolling and filling in where necessary. On a portion of this sub-grade a binder course ¾ inches thick was laid and rolled in place with the hand roller. This binder course was made up using 600 pounds of gravel, 400 pounds of bituminous sand, 150 pounds of coarse local sand and 40 pounds of Portland cement. At all lane and private crossings where vehicular traffic would cross the walk, the binder course was made 4 inches thick to serve as a base for a standard asphaltic concrete surfacing.

The two cars of bituminous sands when manufactured into a surfacing mixture, covered approximately 8,600 square feet. This surface is in good condition to-day. The crown constructed on the narrow walk to throw the water off to the sides, has settled somewhat, but the appearance is still good. We have constructed a large mileage of the class of surfacing, using our standard sheet asphalt mixture, and find that residents and other people using the walk are well pleased.

[1] Formerly Supt. Crown Paving Company.

Subsequently, pending further commercial development of the McMurray deposit to a point that will permit delivery of shipments of bituminous sand at lower cost, imported asphalt cement, combined with local materials, has been used in the further construction of bituminous surfaced walks, in Edmonton. The following statement by Mr. Haddow refers to this type of construction:—

In Edmonton we have approximately 17 miles of walks surfaced with bituminous material and the greater part of these walks have been put in to replace defective plank walks which had outlived their useful life. . . . . . . the asphalt surfaced walks seem to meet the requirements perhaps better than any other type which we have tried. The new walks are built at permanent location for line and grade. This involves often cut and fill. This is done by the ordinary methods of teams, scraper, wagon, and consolidation is obtained by the use of a water-ballasted roller, 28 x 30-inch diameter. Edging pieces of 2 x 4 fir or native tamarac are then set to line and grade and secured to 2 x 4 stakes up to 3 feet in length and spaced 3 to a 16-foot piece. Cinders from the city power plant (the residue from the combustion of our lignite coals) are then filled to a depth of 4 or 6 inches between the edging pieces, sprinkled and rolled with the grading roller noted above until well consolidated.

The bituminous surfacing is then put on to a thickness of 1 inch and the finished walk has a crown of 1 inch. The bituminous surfacing is an ordinary asphalt mixture made up in our paving plant using local sands and imported asphalt—D. grade, Penetration 58-63. The sand grading is approximately as follows:—

Passing	10 mesh	20 mesh	40 mesh	50 mesh	70 mesh	100 mesh	150 mesh
	2·5%	20%	12%	30%	20%	12·5%	2·5%

The batches are made up of 1,000 pounds of the above noted sand and 115 pounds of asphalt. The mixture leaves the plant at about 375° F. and is usually 325° F. or better when it is laid on the street. Our grading gang is made up of 10 or 8 men and team and our asphalt street gang has 11 men with the necessary number of teams depending upon the length of haul, and we top dress an average length of 1,000 linear feet of 5-foot walk per day.

It may be noted that, as regards interruption of pedestrian traffic and damage from flying fragments, repairs to asphaltic sidewalks involve much less inconvenience than in the case of concrete walks.

During September, 1923 and 1924, Mr. Thos. Draper of the McMurray Asphaltum and Oil Co., Petrolia, Ont., supervised the construction of a number of sidewalks in Edmonton, Saskatoon and elsewhere. Bituminous sand,[1] combined with other aggregates secured locally, was used. Certain of these walks inspected by the writer in the Edmonton Exhibition grounds one year after completion, were in excellent condition.

Other applications for which various modified bituminous sand mixtures are adapted, include surfacing of railroad platforms, machine shops, round-houses, decks of railway bridges and of viaducts, cattle-yards, railroad crossings, etc.

(3) Bituminous Sand as a Basis for Manufacture of Compressed Paving Blocks or Slabs

The manufacture of paving blocks or slabs,[2] in which McMurray bituminous sand would be a principal constituent, is apparently entirely feasible. It appears doubtful, however, whether markets at present available in western Canada would warrant commercial production.

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[1] From lease operated by the McMurray Asphaltum & Oil Co., at Waterways, Alberta.

[2] U.S. Patent 853,116 (1907), issued to Clifford Richardson.

In England, compressed blocks have been manufactured for many years, their use being restricted to places where, for some reason, it may not be expedient to construct standard types of wearing surface. At the present time they are used to some extent in the surfacing of roadways, railway platforms, courtyards, cab ranks, dairy yards, and for other floorings of various kinds. It may be noted that this type of construction was introduced into France by Léon Malo in 1872.

In England standard superficial area of such blocks varies, 3 by 3 inches, 6 by 6 inches, 5 by 9 inches, and 10 by 10 inches being used. The thickness varies from half an inch to 2 inches, according to the use for which they are intended. In the United States standard sizes for asphalt blocks are 5 by 12 by 2 inches, 5 by 12 by $2\frac{1}{2}$ inches, and 8 by 4 by $1\frac{1}{4}$ inches. Tiles for sidewalks are made in the following sizes and shapes,—square tiles, 8 by 8 by $2\frac{1}{4}$; hexagonal tiles, $8\frac{1}{4}$ inches on the short diameter by $2\frac{1}{4}$ inches deep. It is claimed by some that, in the laying of compressed blocks, unskilled labour may be employed. This statement is not borne out by the writer's observation.

The process of manufacture is largely automatic. The combined ingredients are fed into moulds, and there subjected to a pressure of approximately 2 to 3 tons per square inch. A standard machine, with 3 to 4 attendants, will produce at least 20,000 blocks per 10 hours.

A low penetration bitumen is used with the result that blocks are more durable and will better withstand traffic conditions, without becoming distorted. Asphalt blocks as now produced, will not indent under standing loads, will not soften or distort under the heat of a torrid sun, and will not become brittle or friable under severe cold. The low penetration bitumen also tends to prevent the blocks from sticking together when stacked for storage, although each tier is also sprinkled with dust or other suitable material.

The blocks when laid possess the chief attributes of a monolithic asphalt surface, being impervious to water, noiseless, dustless, and durable. In England the blocks may be smooth or corrugated, and if corrugated, a frog on the lower face forms a key with the Portland cement base. In the United States, however, blocks are usually smooth. "Anchor blocks" placed in rows at intervals of approximately 15 feet, were at one time commonly used, but improvements in the method of manufacture and increased stability of foundations have gradually eliminated their use.

Asphalt paving blocks may be laid on gravel or macadam, although a concrete base is preferable.

After being laid, two methods are in use for filling joints:—

(*a*) Blocks may be immediately covered with clean, fine sand, screened through a 9-mesh screen. The sand is spread over the surface, swept into the joints, and allowed to remain not less than thirty days, or until such time as the action of traffic on the street will have thoroughly ground the sand into the joints. This is the method most commonly adopted.

(*b*) Blocks may be covered with fine, clean, dry sand which is thoroughly swept into the joints. Excess sand is then removed from the surface of the pavement, and a squeegee coat of bitumen applied in such a manner as to ensure sealing of joints and coating of surface.

A modified block of bituminous concrete is sometimes used in connexion with the construction of foundations for certain types of machinery, in order to minimize vibration.

In the United States[1] the manufacture of asphalt blocks was begun in San Francisco in 1869. In 1880, improved design in mechanical presses placed the industry on a firm footing. The blocks have been used for a variety of purposes, and many excellent examples of this type of surface may be seen in New York, New Jersey, Florida, Pennsylvania, and elsewhere.

At the present time there are apparently only three companies making paving blocks in the United States. All of these use presses and methods recommended by the Hastings Pavement Company. Even within highly industrialized areas, the use of these blocks, as compared with other types of wearing surfaces, is limited. The total area laid prior to 1922 was approximately 19 million square yards, of which 3 million square yards was laid in New York. Present annual production is somewhat in excess of one million square yards.[2]

Construction of an asphalt paving-block plant was commenced at Lessines, Belgium, immediately prior to 1914. Completion was delayed during the war, but the plant is now in operation. Methods of manufacture are similar to those adopted in the United States.

Some years ago, Mr. J. S. Downard,[3] of the Continental Asphalt and Petroleum Company, undertook the manufacture of paving blocks from rock asphalt quarried in Oklahoma. No definite information is available regarding the results of this work.

(4) Separated Bitumen Combined with Clay (or Loam) and Sand Aggregates

It is anticipated that commercial development of the Alberta deposit of bituminous sand, will render available at moderate cost, material suitable for the surfacing of country roads in the provinces of Manitoba, Saskatchewan, and Alberta. An important factor to be considered in connexion with such construction is the difficulty frequently met with in these provinces, of securing supplies of sand and of crushed rock. There is usually available, however, an abundance of clay and loam.

If we assume a commercially successful separation process, the following reference to bituminized-earth pavements becomes of interest.

During the past fourteen years, attempts have been made in the United States to introduce a type of wearing surface consisting of clay or loam properly combined with a suitable bitumen. This type of surface is known as the National pavement.[4] It is claimed that primary rocks from which the clay or loam aggregate is derived have through long periods of time, become completely disintegrated and that such material,

[1] Asphalt Block Pavement. Brochure No. 15, issued by the Asphalt Association, New York. See also literature issued by the Hastings Pavement Company, 25 Broad St., New York.

[2] The estimated area of asphalt surfaces laid in the United States during the past 15 years is approximately 900,000,000 square yards. The area laid in 1924 was approximately 140,000,000 square yards.

[3] 2807 Throckmorton St., Dallas, Texas.

[4] The following patents on this type of surface are controlled by the National Pavements Corporation, 247 Park Ave., New York. (Additional patents are pending). U.S. Patents Nos. 942,866; 1,008,433; 1,013,512; 1,062,113; 1,062,552; 1,076,782.

See also literature issued by this Corporation.

if properly waterproofed, presents an " impervious, voidless and dense physico-chemical combination ". In other words, the particles which comprise the aggregate, cannot be further disintegrated.

The plants now controlled by the National Pavements Corporation represent a considerable degree of mechanical perfection. Clay or loam is delivered to a rotary drier, and heated to a temperature of approximately 350° F. A sufficiently powerful induced draft carries a large percentage of the finer material from the drier through a series of cyclone dust collectors, while the coarser material passes from the drier to a specially designed pulverizer. The product from pulverizer and dust collectors passes to rotary screens, where all material coarser than 40 mesh is removed. The remainder, together with a percentage of sand, is introduced into a pug mill, where it is combined with the required amount of asphalt cement.

Prior to 1917, the writer had occasion to prepare a report on certain wearing surfaces constructed under National Pavement patents in Scranton, Pa., Independence and Kansas City, Mo., and in Iola, Kan. Certain of these surfaces when examined in 1916, were in excellent condition after maximum periods of two years, whereas others had developed marked defects. Such defects included waving, cracking (longitudinal and transverse), crumbling in spots, disintegration where drainage was interrupted, and caulk marks. These defects, in part at least, may be attributed to poor foundations and subsidence of same; excavations for sewers, etc.; poor workmanship, and inadequate supervision resulting in overheating and lack of uniformity; selection of unsuitable soil, and failure to vary percentage of incorporated bitumen, in accordance with variation in fineness or voids in the mineral aggregate. Moreover, it is now recognized that (prior to 1917) equipment used for preparation of aggregate and for heating and mixing was quite inadequate to produce satisfactory results. Consequently, in certain instances, results referred to above have constituted a basis for somewhat severe criticism.

During 1917 and subsequent years, somewhat extensive areas have been surfaced with National pavement. Examples of this type of construction in typical eastern territories, may be seen in West Haven and New Haven, Connecticut; and in Millburn, Passiac, West Orange, East Orange, South Orange, Patterson, Nutley, Bloomfield and Montclair, New Jersey. Certain of these pavements have been subjected to very heavy traffic, but others are on residential streets where traffic is relatively light. A number of these surfaces were recently inspected by the writer and, for the most part, appeared to be in excellent condition. In California a large aggregate yardage of surface has been completed or is under contract in Los Angeles county, Venice, Englewood, Culver City, Hormosa Beach, Maywood, Glendale, and elsewhere. More recent contracts include an area of approximately 100,000 square yards in Gainsville, Texas.

High penetration asphalt cement is used in the preparation of bituminized earth mixes. The fact that bitumen derived from Alberta bituminous sand has a high penetration would thus favour its use in the construction of this type of surface. On the other hand it is considered that water-soluble salts in clay or loam aggregates are objectionable, although the permissible percentage of these has not been determined.

Many of the earlier National pavements were composed almost entirely of dried pulverized clay (or loam) combined with from 17 to 18 per cent of asphalt cement. More recently the mixtures have been modified to include a percentage of sand. An excellent piece of surface observed by the writer in New Jersey, consists of equal amounts of pulverized clay and of sand combined with 15 per cent of asphalt cement. The wearing surface is 1 inch in thickness on a 1½-inch binder course. The base consists of scorified macadam.

Mixtures adopted in the construction of wearing surfaces referred to above, vary as regards relative percentages of sand and pulverized clay and in the percentage of incorporated bitumen. Obviously, uniformly satisfactory results should not be expected under such conditions, since finely divided mixtures carrying a high penetration bitumen must be quite sensitive to variation in percentage of bitumen.

It also appears that material passing 200 mesh varies considerably, according to the locality from which it is obtained. In view of the fact that a proper balance must be obtained between this fine material and the percentage of bitumen used, a determination of the proper relative proportions of bitumen when combined with various fine aggregates should be established. As regards the associated question of penetration, it appears that this should be as high as 85° (Dow) owing to the relatively large percentage of 200-mesh material in all the mixes used.

The use of fine aggregates referred to above, implies a somewhat high percentage of asphalt cement in the surface mixture. When the original bitumen content is sufficiently high, however, it appears that the use of certain grades of bituminous sand from the McMurray area, combined with properly prepared clay or loam, should give satisfactory results. When suitable clay or loam is available locally, the use of such a mixture, —as opposed to a mixture consisting entirely of bituminous sand—would appreciably reduce freight charges.

It is of interest to note that the U.S. Bureau of Public Roads has approved National pavement, when suitably designed and specified under rules and regulations of the Department of Agriculture, for use on Federal aid projects.

(5) Bituminous Sand Combined with Various Percentages of Clay and Other Aggregate

In November, 1923, a demonstration pavement was laid by the Public Works Department of the province of Alberta, under the supervision of Mr. Ritchie, Highways Engineer of that Department, and Mr. Walter Draper. The site selected was on the St. Albert trail, adjacent to the Alberta and Great Waterways railway station, North Edmonton. The width of the pavement is 16 feet and the total length 806 feet. The following summary[1] indicates the length of each section and composition of wearing surface. Sections are numbered from southern end of pavement.

Section 1. Length 350 feet, thickness 5½ inches, consists of 50 per cent bituminous sand[2] combined with 50 per cent Huff's crushed gravel. Mixed 30 minutes at a temperature of approximately 300° F.

[1] The summary is furnished by Mr. A. W. Haddow, City Engineer, Edmonton.
[2] Supplied by McMurray Asphaltum and Oil Co.

Section 2. Length 160 feet, same as section No. 1, but the thickness of wearing surface is 4½ inches.

Section 3. Length 95 feet, 2-inch base composed of Huff's gravel; bituminous sand, 1 inch in thickness, heated sufficiently for spreading; one barrow of gravel for each 48 square feet of surface, wearing surface 2 inches thick similar to that used on section No. 1.

Section 4. Length 104 feet, 2 inches of gravel (rolled); bituminous sand 1 inch in thickness, surfaced with gravel as in section No. 3; bituminous sand 1 inch in thickness surfaced with gravel as in section No. 3.

Section 5. Length 47 feet, 70 per cent clay combined with 30 per cent bituminous sand. The clay was first heated and pulverized and then mixed with bituminous sand at a temperature of 300° F.

Section 6. This constituted the northern end of the pavement and consisted of 2 inches of compacted gravel, sprinkled with clay.

Materials were heated (and mixed by hand) on a sheet-iron plate—a method not conducive to best results.

(6) Bituminous Sand as a Basis for the Preparation of Asphalt Mastic[1]

It appears that there is, in Canada, a promising field for the extensive use of mastic for various purposes.

Mastic had been successfully employed in Europe, to a very limited extent during the early part of the 18th century, having been introduced as a substitute for lead linings by Dr. Eyrinis. Its general use in France commenced in 1838, with the construction of the first mastic footway (sidewalk) in Paris. Subsequently, largely through the efforts of W. H. Delano, its use for a variety of purposes was extended to England. In Canada and the United States, the present use of mastic is confined chiefly to surfacing of sidewalks and floors, waterproofing of railroad bridges, and the lining of reservoirs and tanks. A fairly comprehensive reference to American practice will be found in "Asphalt and Allied Substances," by Herbert Abraham.

It should be recognized that definition of the term "asphalt mastic" is somewhat elastic. The material may, however, be described as a dense bituminous mixture, containing from 25 to 40 per cent of aggregate passing a 200-mesh screen. Of the remainder, not more than a trace should remain on a 10-mesh screen. Associated bitumen may vary from 15 to 20 per cent of the whole. The mixture, when hot, should be of such consistency, that it can be readily "floated," that is, laid by hand when in a semi-liquid condition. When tapped from the mastic heater into buckets, it should not offer undue resistance to a wooden paddle thrust into it, nor should it adhere to the paddle. Theoretically it should also be possible to draw a very fine mastic thread of perfect cohesion.

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[1] Referred to in the following pages as mastic. Of the many books dealing with this subject, the majority represent more or less free translations or reproductions of previous works. The following may be mentioned as reasonably accurate:—

L'Asphalte—Léon Malo, Paris, 1898.
Twenty Years' Practical Experience of Natural Asphalt and Mineral Bitumen, W. H. Delano, 1893.
Traité Pratique des Travéaux en Asphalte. P. Letouze and P. Loyeau, Paris, 1897.

Prior to 1914, certain natural rock asphalts from Italy, France and Switzerland,[1] combined with the necessary percentages of bitumen, were largely used in the preparation of European mastics, and it had been claimed—and generally accepted—that a satisfactory product could not be prepared by synthetic methods. During the period 1915-18 however, the impossibility of securing supplies of natural rock asphalt, necessitated the use of various percentages of unimpregnated limestone, and it appears that results, as a whole, have been satisfactory. Both hard and soft limestones have been used, although in the case of the former, on account of the difficulty of impregnating the particles of the aggregate, a larger percentage of 200-mesh material is required. It should also be remembered that when newly applied, good, bad and indifferent mastics may look equally well. A few months' time will usually suffice to differentiate between them. The following may be considered as representative analyses of good standard mastics:—

	Per cent	Per cent
Bitumen (sol. in CS_2)—		
Penetration 40° to 45° Bowen	16·5	17
Passing 200 mesh	34	40
" 100 "	15	11
" 80 "	5	2
" 50 "	10	10
" 40 "	5	6
" 30 "	4·5	3
" 20 "	2·5	5
" 10 "	5·0	4
On 10 mesh	2·5	2
	100·0	100

For certain applications, the above figures are susceptible to variations of 25 to 30 per cent. For general use in England, the penetration of the bitumen will range from 35 to 40° (Bowen). Under untried climatic conditions, careful experiments must determine the penetration required.

In order to produce good mastic, care, experience, and the selection of suitable materials, are essential. Commercially, success will depend largely on internal organization, and in securing raw materials under favourable terms and conditions. Such experience can only be attained by familiarity with, and actual handling of the various materials used.

Bitumen commonly used in certain European factories, consists of approximately 50 per cent Trinidad épuré, combined with 50 per cent Mexican "E" petroleum residuum suitably fluxed to give the desired penetration.

A limestone much used in the preparation of mastic in certain London plants, is a soft, somewhat chalky, amorphous and almost pure rock. In other plants, it is claimed that a harder crystalline limestone has given even better results. It is said that, with the use of soft limestone, the mastic shows a tendency to develop minute cracks, this being probably due to subsequent crystallization. When hard limestone, which is less absorbent than the soft variety, is used, at least 40 per cent of the aggregate should pass 200 mesh. Any deficiency of this mesh material may, however, be corrected by the addition of Portland cement, or any of the other suitable fillers.

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[1] European rock asphalt ("asphalte") may be defined as carbonate of lime, naturally impregnated with pure bitumen, to form an homogeneous whole. (See definition of bituminous sand, Appendix I.)

The usual practice is to reduce the limestone by passing it through rolls (or rock breakers) and disintegrators, and great care must be used in the selection and adjustment of equipment, if a satisfactory grading is to be obtained. In one London plant, it has been found that a beater disintegrator, fitted with $\frac{3}{8}$-inch mesh screens, and followed by a pair of trommels with 16-mesh covers, gives only 10 per cent oversize, and does not make too high a percentage of "flour." The use of a Cyclone dust-catcher has given satisfactory results.

In the preparation of mastic, bitumen is first charged into the heater, and the aggregate slowly added. As the mixed bitumen and aggregate become homogeneous, further amounts of each are introduced. When "cooking" is complete, the charge is drawn off into buckets, and poured into moulds, each of which usually holds approximately 56 pounds. The inner surface of the mould is usually—but not always—painted with liquid silt or other suitable material, which will prevent sticking. The surface of the mastic "cake" is stamped with the company's registered mark.

Of the commoner uses to which mastic is applied, certain examples may be given. When used in connexion with building construction, specifications are usually furnished to the asphalting contractors by the architect. In such work, the mastic is laid to the various thicknesses specified, usually in two or three layers, with properly lapped joints and fillets at intersections. It should be remembered that, in itself, mastic has comparatively little strength, and must be adequately supported by other construction.

Footways and Floorings. It is said that there are in England, many mastic footways (sidewalks), which at the end of more than 15 years, have required no repairs. It has been estimated that, prior to 1914, first cost and maintenance of footways in Paris amounted to less than 6 cents per square yard per year.

In the successful use of mastic for the above class of work, a properly prepared rigid base—commonly 3 inches of concrete—is used. Attempts to lay the wearing surface on other than a rigid base usually result in failure. The percentage of grit to be incorporated in the mastic may vary from 40 to 60 per cent of the mastic used, depending largely on extremes of temperature to which the surface will be subjected. The resulting mixture must, however, be sufficiently liquid to permit of proper 'floating'. After the gritted mastic has been floated, very fine sand—slate dust is satisfactory—is rubbed over the surface, the surplus sand being subsequently brushed off. This rubbing with new sand tends to equalize any slight roughness, closes up the surface, and thus gives increased wearing resistance. By absorbing any traces of surplus bitumen, it also tends to counteract softening during warm weather.

In the preparation of gritted mastic, the following approximate quantities of materials may be incorporated in the mixture:—

	Per cent
Mastic, 300 lbs.	54–63
Bitumen (usually Trinidad épuré) 15 lbs.	2·7–3
Grit, 240–160 lbs.	45·3–34

The grit may consist of crushed granite or quartz, all of which should pass a $\frac{1}{8}$- and be retained on a 50-mesh screen. A square yard of gritted mastic $\frac{6}{10}$ inch thick will weigh about 65 pounds.

A representative analysis of a satisfactory gritted mastic may be given as follows:—

	Per cent
Bitumen (sol. in CS_2)	11·5
Passing 200	25–30
" 100	16
" 80	6
" 50	10
" 40	6
" 30	4
" 20	2
" 10	5
On 10	14–9·5

It should be noted that for heavier traffic, as in railway courtyards, baggage-rooms, armouries, etc., granite chips, all of which will pass a ¼-inch mesh and be retained on a 10 mesh, are substituted in place of the usual grit. This modified mixture is known as granitted mastic.

The use of mastic in places where heavy trucks halt for considerable periods, as for example beside freight-shed platforms, is not recommended, since rutting of the surface is inevitable. Moreover, leakages of vegetable oils, (as palm oil, olive oil, cocoanut oil, etc.) cause deterioration.

Another type of sidewalk surfacing, may be constructed by combining 10 parts of 15 per cent mastic with 10 parts of crushed rock or gravel. This also is laid on a 3-inch concrete base. If constructed adjacent to buildings a slope of 1 in 50 is sufficient; otherwise the convexity of the surface should not exceed 1 in 100. Where there is danger of infiltration of rain water into adjacent buildings, a fillet of pure mastic should be laid along the junction between wall and sidewalk. Mastic sidewalks set very quickly, and may be opened to traffic 6 hours after completion. It has been found that a thickness of ¾ inch is generally sufficient. The mixture is laid while hot and is floated by hand.

Mastic Roofing. For this work a dense mastic is required. The mastic may be laid directly on concrete surfaces, but Hessian felt, metal lathing or other suitable material, is interposed when the supporting surface is of wood. Roofing is usually applied in two layers of ⅜-inch thickness, and joints broken to avoid leakage.

Mastic Damp-courses. These are usually laid below ground level. Range of temperature and weight to be supported will govern the final composition of the mastic, as well as the penetration of the bitumen itself. When heavy weight is to be supported the percentage of bitumen in the mastic should not exceed 13, and penetration will be from 20 to 30° (Bowen).

If the weight is not great, a 16 per cent mastic may be used provided heat is not excessive, as between 35°-75°F. The average thickness of damp-courses is ½ inch. Actual tests are of course necessary in connexion with the use of any new and untried type of mastic.

Powder Magazines and Explosive Factories. For this class of construction mastic makes an ideal flooring. Mixtures must, of course, be absolutely free from gritty particles. A straight natural rock asphalt powder, or a pure crushed limestone combined with a pure bitumen, should be used.

Foundations for High-speed Machinery, Engine-beds, Heavy Hammers. Before 1900, the value of asphaltic concrete for the isolation of vibrational disturbances was recognized, and in a number of well-known instances gave satisfactory results under exacting conditions. Certain of the earlier foundations so constructed contained several cubic yards of asphaltic concrete, though in later construction the thickness of the insulating bed was much reduced.

Such construction apparently depended on the principle that, although relatively thin asphaltic sheets may become seriously deformed under certain conditions of heat and pressure, yet when compacted into more massive rectangular forms, the stability of the material is very greatly increased.

Fifty per cent of mastic combined with 50 per cent of crushed hard rock will give satisfactory results. A heavy 2-inch plank form is first constructed, in which tapering hardwood bolt boxes are placed. Plank form and bolt boxes are lined with heavy paper. The asphaltic concrete is then built up in layers, 3 to 4 inches thick, each successive layer being properly keyed to the one immediately below. Mastic, heated to 350° to 400° F., is poured into the form, and the crushed rock, heated to the same temperature, is then introduced. Care must be taken that all voids be filled to the greatest possible extent. When the plank form has been filled in this manner, the foundation bolts are placed in position, and mastic poured into the wooden bolt boxes. If desired, blocks of cut stone may be let into the surface of the asphaltic concrete, for the support of cylinders or other special parts of the apparatus to be installed, or the whole surface may be protected by a slab of Portland cement. The greatest care, combined with experience, are essential to ensure successful results.

Apparently such installations are now chiefly of historic interest, and have been largely superseded by the use of rubber, hair felt or cork, or combinations of these utilized in different ways by various well-known systems.[1]

Waterproofing Courses for Arches of Viaducts, Bridges. Heavy masonry frequently settles to a certain extent. Under such conditions coating with Portland cement furnishes no protection either against leakage, or as a waterproofing of the masonry itself. Mastic has, however, sufficient strength and elasticity to adjust itself to such slight settling as is usually met with.

Fire-roofing. It is claimed by some that, in the event of fire, a mastic roof, in subsiding, will often act as a blanket and extinguish the flames. It is also claimed that rooms in which valuable papers, etc., are stored, may be rendered absolutely fire-proof if walled with bituminous concrete. It appears, however, that claims advanced for the use of asphaltic materials for such construction have been somewhat exaggerated. At present the use of mastic in the surfacing of platforms of underground tube-stations in London is prohibited, as it is considered that the material is to some extent inflammable.

[1] Electrical Review, vol. 77, No. 1, pp. 505-08, 1915.

Floorings for Laboratories. The use of mastic for such work is open to criticism. No asphalt mastic is completely acid-proof and, moreover, substances tend to adhere to and accumulate on the surface. For this class of work, however, a mastic very similar to that used in the lining of acid-proof tanks may be used.

Acid-proof Mastic. This may be used either for the construction of laboratory floors, or the lining of tanks for the storage of certain acids. It may be noted that bitumen will not resist the action of nitric or sulphuric acid that is over 50 per cent pure.

Acid-proof mastics are a combination of bitumen and silica. Coal-tar pitch and slate dust have also been found satisfactory. The following may be given as representing a typical mixture for acid-proof mastic:—

	Parts
Sand	6
Granite dust	3
Blown granite powder	9
Épuré	14
Mexican 'E'	4

In laying, the mastic is keyed directly to the clean wall, or an intermediate paint course may be used. Two courses, each of $\frac{3}{8}$ to $\frac{1}{2}$-inch thickness, are customary, or a single course, if work can be carried out continuously.

In 1919 the writer designed and prepared in London, England, samples of asphalt mastic, in which Alberta bituminous sand was largely used. A time test under actual climatic conditions is of course necessary to prove their value. An attempt was made to use a maximum amount of bituminous sand, and to incorporate therewith, minimum amounts of powdered limestone and bitumen. The relative proportions of materials used are as follows:—

	Per cent
Alberta bituminous sand	64
Medway marl	32
Trinidad épuré	4

At the same time it was recognized that:

(*a*) In the past satisfactory mastics had contained practically no silica sand, with the result that the particles of the aggregate had been impregnated rather than merely coated with bitumen.

(*b*) Limestone powder permits of more complete impregnation, and results in a mastic which is smooth and easily floated.

(*c*) A rigid grading of the aggregate is not essential, provided the volume of voids does not involve too large an addition of bitumen. Obviously, an aggregate grading on only two or three meshes would have too large a volume of voids.

In most good mastics, the percentage of material passing the 200 mesh exceeds the material passing the 100 mesh. The amount passing the 200 mesh should not be less than 35 to 40 per cent, and 10 to 15 per cent should pass the 100 mesh. Not more than 1 per cent should be retained on a 10-mesh screen.

As already noted, it appears that there is in Canada, a field for the use of mastic for a variety of purposes. Should a successful commercial separation process be developed, all ingredients required in the preparation of the mastic could be secured within the McMurray area.

In preparing synthetic mastic from the somewhat hard fossiliferous McMurray limestone and separated bitumen, the character of the limestone

is of great importance, and until it has been thoroughly tested by actual experiment no definite statement can be made. Analyses of two representative samples of limestone secured near McMurray, are given as follows:—

A. Sample from Paul Miller's ledge along east shore Athabaska river (sec. 28, tp. 89, range 9).

B. Sample from ledge between Hudson Bay store and Horse river along east shore Athabaska river (sec. 19, tp. 89, range 9).

	A	B
Calcium carbonate *a*	86·21	75·78
Magnesium carbonate *b*	5·60	7·81
Alumina	0·74	1·30
Iron oxide	0·79	1·44
Sulphur trioxide	0·16	0·17
Insoluble mineral matter*c*	5·90	11·46
*a*Equivalent to lime	48·31	42·44
*b*Equivalent to magnesia	2·68	3·74
*c*Combined silica in (A) is 0·96 and in (B) is 1·01		

The merits of hard crystalline limestone and of softer varieties have yet to be determined, though the character of the added bitumen used will affect the decision. Thus a soft finely ground limestone would counteract to some extent the defects of a very soft bitumen, such as is derived from Alberta bituminous sand. On the other hand, a hard crystalline limestone would carry a harder bitumen. Probably a mixture of 40 to 50 per cent hard limestone and 40 to 50 per cent soft limestone would give good results.

Soft limestone, when ground, usually gives a high percentage of fines (much of it "flour") which would absorb too much bitumen. In floating it would also be sticky, and show uneven grading of the meshes between 50 and 100. The addition of the harder crushed limestone would correct this grading, and prevent undue absorption of bitumen which is the most expensive ingredient.

The first consideration is that the mastic should float readily, since labour charges are an important item, and yet not be too soft when laid. McMurray bitumen has a high penetration, which can be easily reduced to any desired degree during a period of a few hours in a mastic "cooker." Moreover, the lighter oils in the McMurray bitumen may prove an advantage in facilitating impregnation of the limestone. A hard limestone being largely impermeable would require less "cooking." The balance evidently lies between a hard short-cooking limestone which may be "short" when laid, and a soft absorbent limestone which will absorb more bitumen, but which will be more homogeneous and more easily floated. Care must be used in the selection and adjustment of machinery for crushing the raw limestone, in order to secure the desired aggregate.

In experimental mixes small quantities (less than 500 pounds) tend to result in overheating, even with agitation, and are thus unsatisfactory.

In 1920 experiments were carried out in England looking to the preparation of purely synthetic mastic, and its commercial application was subsequently introduced. A small shipment of bituminous sand has recently been forwarded to the Limmer and Trinidad Lake Asphalt Co., London, England. The material will be used in carrying out tests with the view of utilizing it in the preparation of asphalt mastic

CHAPTER IV

PROSPECTING AND MINING

PROSPECTING

The necessity of careful and systematic prospecting as a preliminary to actual development is, of course, obvious, and until this has been done, it is impossible to definitely express an opinion regarding the value of any area, or the mechanical appliances best adapted to mining development. Incidentally, it may be noted that a certain degree of danger attends the examination of large outcrops. During warm weather, large and small masses of bituminous sand flake off and fall from exposed faces, and after rains, heavy slides of loosened material are frequent along the more precipitous outcrops. The following are among the more important conditions to be considered.

Even a casual consideration of sections designed to accompany the present report, will indicate the importance that will attach to overburden, since everywhere the bituminous sand is overlain to some extent. In certain cases, gravels and clays, in others, stratified sandstones, shales and occasional thin quartzites, constitute the overburden. In many instances, low-grade highly banded bituminous sand must also be classed as overburden, and removed as such.

As indicated in Table I of this report, a large part of the area to the north of McMurray is covered by muskeg, and drainage will therefore constitute a serious—and in places possibly an insuperable—difficulty. Bordering the valleys of various streams, as is usual in muskeg areas, the influence of local drainage has resulted in the formation of slightly elevated narrow dike-like zones of dry ground, usually from one hundred to four hundred feet in width. Typical illustrations of otherwise promising areas of bituminous sand which are subject to such conditions occur in secs. 21 and 29, tp. 92, range 9, and in secs. 21 and 28, tp. 95, range 11. If stripping of overburden is attempted in areas such as these, removal of the dike zone bordering a stream-valley, will necessitate the development of an adequate drainage system to provide for a large volume of water from extensive adjacent areas of muskeg. In certain sub-areas not immediately adjacent to valley slopes, minor local ridges (as for example in sec. 23, tp. 95, range 11) in many places constitute important dams. Obviously, therefore, in areas where commercial development is contemplated, not only should the thickness and character of the overburden itself be considered, but also the associated problem of drainage.

Prospecting may be undertaken either by manual labour, or by the use of power-drills. The method adopted will depend on topographical features, thickness and character of overburden and of bituminous sand, and on extent of the area to be prospected.

(a) Manual Labour

It may be possible to expose a complete section of bituminous sand and overburden, although this will frequently necessitate a large amount of trenching through heavy slide. If however a section is exposed in this manner, samples of the bituminous sand may be secured by boring with suitable asphalt augers. The shank of the auger used by the writer is of $\frac{7}{8}$-inch steel, the auger itself being 2 inches in diameter with seven turns to the foot. The cutting edges are drawn to a chisel edge, $2\frac{1}{2}$ inches diameter, and nearly at right angles to the stem. Boring rods of 1-inch steel, and in 10- to 12-foot lengths, joined by means of sleeve couplings, have been found satisfactory for holes up to 20 feet in depth. In order to secure a downward pressure, circular movable weights, slotted at the side, and supported by a collar held in place by set-screws, may be used. A light adjustable tripod and collar may at times be found convenient, since considerable care is required in holding the rods at the desired angle. In boring, it is necessary to lift the auger at frequent intervals in order to clear the hole. The use of a block, suspended from a tripod, is therefore suggested. The occasional introduction of small quantities of petroleum distillate into the hole is of assistance in "cutting" the bitumen, and preventing the auger from sticking. Boulders or hard strata are passed through by the use of drill steel.

No serious difficulty is experienced in sinking individual vertical holes to a depth of 20 feet by the use of augers. Where it is necessary to pass through heavy beds of outcropping bituminous sand, however, it is desirable to carry down a series of short bores, each succeeding bore being commenced at a point corresponding in elevation with the bottom of the bore immediately preceding.

In areas where the overburden is comparatively light, as for example in river bottom lands of limited areal extent, shafting to reach the bituminous sand has proved satisfactory. As a rule if dimensions of such shafts do not exceed 4 by 5 feet, little timbering is required to a depth of 40 feet. For such a depth, two men will sink at an average rate of $2\frac{1}{2}$ feet per day of 9 hours. From the bottom of the shaft, a bore may then be sunk into the bituminous sand, and accurate core samples secured by means of augers.

Bituminous sand, especially when unaffected by weathering, disintegrates rapidly, with partial or complete separation of associated bitumen, when acted upon by water. If borings are made by means of augers through bituminous sand, free from water, the material adheres to the auger, and may be readily withdrawn from the hole. On the other hand, when water is present, auger cuttings are rapidly altered to a wet, non-adhesive pulp, which will not adhere to augers or other cutting tools. This appears to constitute one of the principal difficulties that will be encountered in recovering core samples of bituminous sand. Consequently after passing through the overburden and into the bituminous sand, care should be taken to ensure dry holes, by sealing off the water.

In 1920, the writer prospected an area on Horse river, by trenching and shafting supplemented by the use of augers. In all, 20 pits averaging

from 9 to 35 feet in depth, and 4 trenches, of varying dimensions, were excavated. Eight men were employed and the time required was approximately 8 weeks.

(b) Power Drills

In prospecting at points where overburden is relatively heavy, some type of power drill may be used with advantage. Light, portable drills of various makes, but of the same general type, are well known and require little comment (Figure 7). Such equipment is essential in the McMurray area where slopes are frequently abrupt and roads practically non-existent.

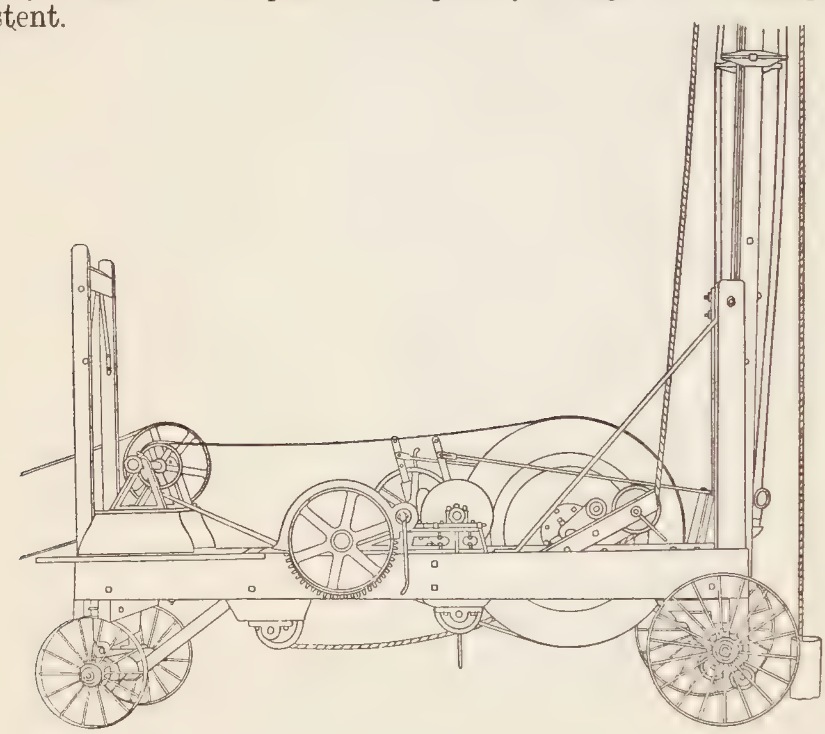


Fig. 7.—Typical portable drill suitable for passing through overburden in prospecting bituminous sand.

Drilling mechanism for operating cable tools, mounted on a frame and trucks, and driven by a gasoline tractor—rather than by an engine mounted on the frame itself—will give satisfactory results in passing through overburden. When not required in connexion with actual drilling, the tractor will be found valuable for moving equipment and for other auxiliary purposes. Instead of a derrick mounted on the truck itself, a three-pole derrick can be used to advantage. The use of 6-inch casing is suggested.

On reaching the bituminous sand some form of rotary tools, such as a heavy type of auger $2\frac{1}{2}$ to 3 inches in diameter, may be used, although pipe with a saw tooth or other form of cutting edge has also given satisfactory results. Such tools may be rotated by various methods, but a light rotary table operated by hand power should answer requirements. A 50-foot pole derrick can be easily placed in position and will give sufficient head room to handle the rotary drill rods expeditiously.

REMOVAL OF OVERBURDEN AND MINING

Since 1913, the writer has excavated from residual river bottom deposits approximately 140 tons of bituminous sand. Overburden immediately adjacent to the outcrop excavated, was first removed by the use of hand tools. Approximately two feet of altered bituminous sand[1] was also removed; shallow holes being bored by means of hand augers, and the material being broken up by light charges of powder. Holes from 7 to 8 feet deep, and with approximately 6 feet of cover, were then bored into the bituminous sand, which was readily broken down by a charge of 10 to 12 pounds of black powder per hole. If, during warm weather, the material thus broken down was allowed to lie for twenty-four hours, it re-solidified to a considerable extent. However, heated spades easily cut the partly compacted fragments into cubes of 10 to 12 inches.

Removal of Overburden

Topographical conditions, water supply, and thickness and character of overburden will, of course, largely determine the method to be adopted. Subsequent disposal of waste material will, in certain instances, constitute a serious problem. As an illustration, the area reserved for the Parks Branch, Department of the Interior, on Horse river, may be mentioned. The material overlying bituminous sand of commercial grade is chiefly low-grade, worthless bituminous sand, somewhat soft sandstones and Clearwater shales. In the low-lying river bottom lands, overburden consists altogether of gravel, sand, and clay.

Assuming that the shales will stand at a slope of 1 to 3, and low-grade bituminous sand at a slope of 1 to 1, it is estimated that the mining of 3,360,000 tons of bituminous sand will involve the removal of approximately 3,180,000 cubic yards of overburden. This estimate probably represents a condition somewhat more favourable than is usually met with at points adjacent to present rail transportation. In descending Athabaska river, however, thickness of overburden gradually decreases; the ratio between overburden and bituminous sand becoming much more favourable to quarrying operations.

During recent years, methods adapted to large-scale stripping and mining operations have reached a high state of development. Only specialists thoroughly familiar with the most recent practice, are competent to express an opinion regarding procedure best adapted to individual problems. It is quite beyond the scope of the present report to attempt a detailed discussion of stripping and mining methods, and the following notes should therefore be regarded merely as furnishing a general reference to certain methods that have found a wide application.

Under conditions prevailing in the McMurray area, overburden may be removed and wasted by any of the following methods: viz., dragline machines, shovels, tower-excavators,[2] shale-planers or hydraulicking. Each of these methods under favourable conditions has proved efficient.

[1] In residual river bottom areas where bituminous sand has been exposed to water erosion with subsequent deposition of river wash, gravel has become embedded in the upper surface of the bituminous sand to form a hard conglomerate capping 8 to 20 inches in thickness. The removal of this conglomerate presents some difficulty. Where the section of bituminous sand is intact and the original overburden undisturbed, this intermediate stratum does not occur.

[2] Generally used for river and large-scale canal excavation rather than for removal of overburden.

Dragline Machines. During recent years dragline excavators have been developed to a high degree of efficiency, and under suitable conditions, are adapted to stripping and mining. The dragline machine is, as yet, only occasionally used in digging blasted rock or the hardest types of clay, but has been used successfully in fairly tough clay and in easier digging. With older types of standard railroad steam shovels, only the boom and its attachments swing, whereas with the dragline the entire machine revolves, with the exception of the base. In the Florida and Tennessee phosphate fields, the stripping-machine is followed by a second dragline, which excavates the phosphate. Class of overburden commonly handled includes gravel, clay, silt and loam. Capacity of standard buckets varies from 1½ cubic yard to 6 cubic yards with 50 to 150-foot booms. Prices f.o.b. factory, for the above sizes vary from $25,000 to $90,000.

As opposed to steam shovels, the dragline excavator draws material toward itself from in front and from either side. Moreover, it must be assembled at the site where it is to operate, though various types of support permit of a limited range of movement. A " walking " device is also used to some extent. (Plate XXXII.) Clam shells, orange peels or dragline scraper buckets may be used, depending on character of material to be excavated and local conditions. Material excavated by draglines usually remains where it is deposited, although waste cars may be used. According to Massey,[1] outputs in representative dragline work are as follows:

½ yd. machine	20 to 30	cu. yds. per hour
1 "	35 " 60	" "
1¼ "	45 " 65	" "
1½ "	50 " 75	" "
2½ "	75 " 115	" "
3½ "	100 " 150	" "

It appears that the above estimates are conservative.

Typical cuts for draglines are as follows:—

100-foot boom	120 feet wide and	15 feet deep (minimum)
125 "	150 "	20 " "
155 "	175 "	30 " "

Dragline costs vary widely, since performance ability depends on character of material, degree and manner of preliminary preparation (by blasting) in hard ground, personnel of crew, weather conditions, etc. The following costs[2] must therefore be accepted with the above proviso. In 1920, in the Miami Conservancy District, various classes of draglines handled 51,700 cubic yards of material loaded in cars at a reported cost of 13 cents per cubic yard. Another class of dragline handled 982,000 cubic yards at an excavating cost of 8½ cents per cubic yard.

Shovels—Revolving Shovels. (Plate XXXIII). Large revolving shovels are adapted to stripping on bodies of variable thickness when depth of overburden is 65 feet or less. Waste may be loaded on cars either at approximately the same level as the shovel, or at elevations of 50 feet above the shovel track. Shovels of this type are being successfully used at Mesabi

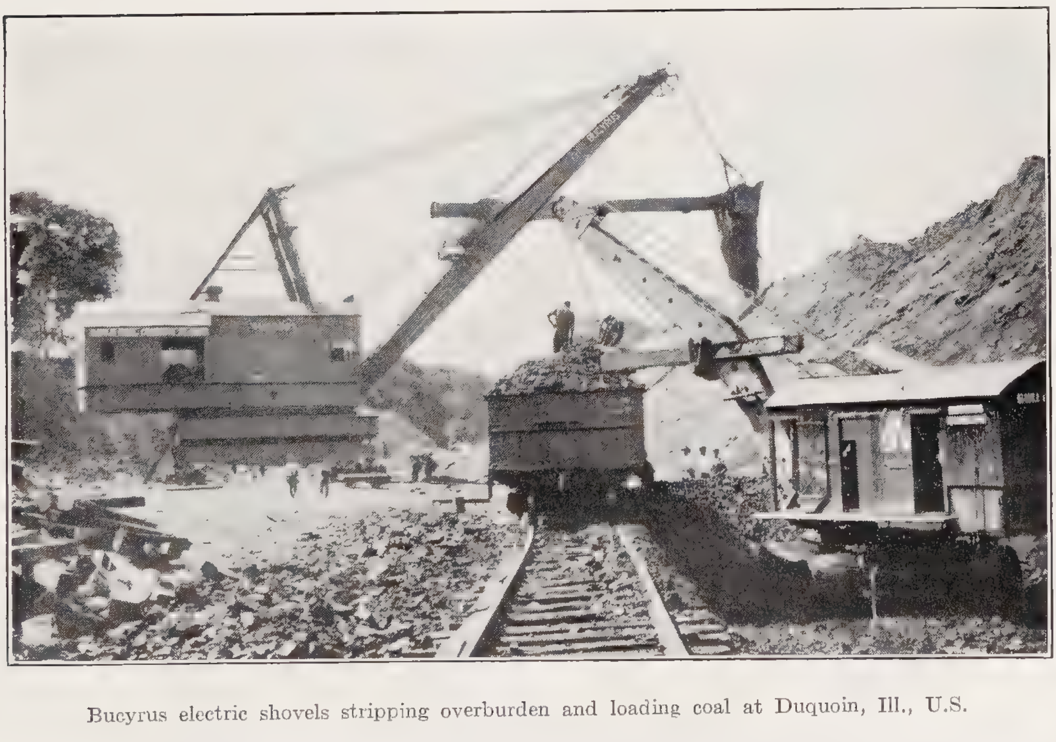
[1] Massey, George B. The Engineering of Excavating. John Wiley & Sons, 1923.

[2] Power plants on this type of equipment may be operated by steam, gasoline, electricity or Diesel engines. Lowest modern dragline costs have been obtained where Diesel engines are used.

Plate XXXII

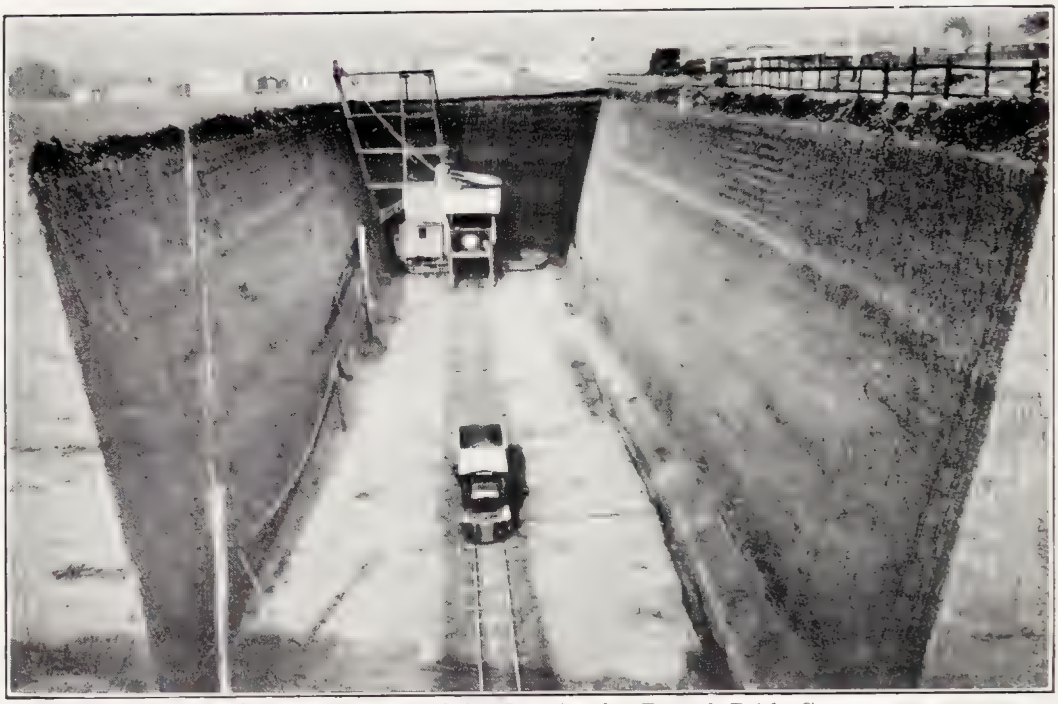
Monighan dragline showing "walking" attachment.

Plate XXXIII



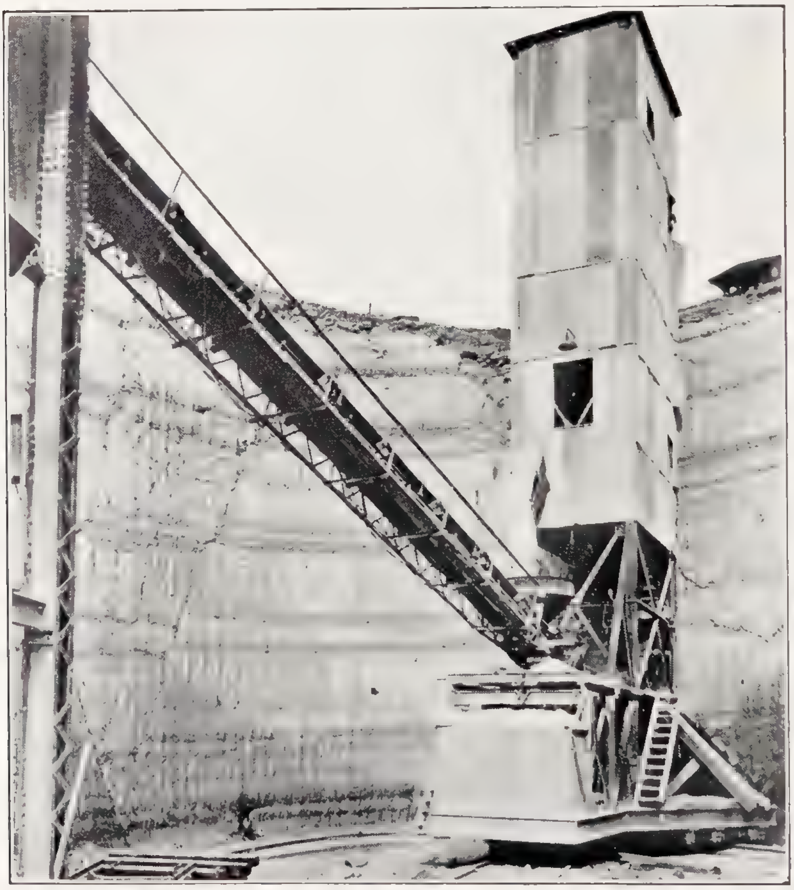
Bucyrus electric shovels stripping overburden and loading coal at Duquoin, Ill., U.S.

Plate XXXIV



Eagle shale-planer operated by Los Angeles Pressed Brick Company.

Plate XXXV



Adel excavator of the Adel Clay Products Company, planing a 48-foot shale bank and delivering 50 tons per 10 hours.

mountain and elsewhere on the Minnesota iron range; for stripping and mining low-grade copper ores, for stripping stone quarries, coal beds,[1] etc., and for canal construction. Digging radius for the larger types of shovel exceeds 100 feet, and width of cut 130 feet. Material may be dislodged at a height of upwards of 70 feet above the shovel track. Drainage is usually a primary consideration in determining the working layout.

According to Massey, the stripping capacity of large revolving shovels, in acres stripped per year for various depths and shovel capacities, is as follows, (based on 10 months of 25 days of 10 hours, or 250 working days):—

Depth of overburden, feet	Cubic yards per acre	Output per 10-hour day, in cubic yards					
		1500	2000	2500	3000	3500	4000
30	48,500	7¾	10¼	13	15½	18	20½
31	50,000	7½	10	12½	15	17½	20
32	52,000	7¼	9½	12	14½	16¾	19
33	53,500	7	9¼	11½	14	16¼	18½
34	55,000	6¾	9	11¼	13½	15¾	18
35	56,500	6½	8¾	11	13¼	15½	17½
36	58,000	6⅜	8½	10¾	13	15	17
37	60,000	6¼	8¼	10½	12½	14½	16½
38	61,500	6⅜	8	10¼	12¼	14¼	16¼
39	63,000	5⅞	7¾	10	12	14	15¾
40	65,000	5¾	7½	9½	11½	13½	15½

Standard Shovels. Standard shovels are used for much the same class of work as large revolving shovels, but their radius of action is somewhat less. According to Massey, the monthly output of such equipment per month of 26 working days of 10 hours each, working single shift, is:—

In sand pit with 90-foot height of bank, sand running to shovel, long lop on dipper in place of teeth, dipper pitched well forward, shovel moving ahead 15 feet at a move, 60,000 cubic yards.

In earth, with standard manganese steel lip, height of bank 20 to 30 feet, no tendency for earth to stick in the dipper, moving ahead 6 feet, no boulders, 40,000 cubic yards.

In hard clay, without blasting, heavy dipper with manganese teeth and tooth tips, 6-foot moves, bank 20 to 25 feet high, material stratified and known as shale, 25,000 cubic yards.

In blasted rock, blasting being properly done ahead of the shovel, 17,000 cubic yards.

Under any of the conditions named above, it would not be safe to count on a larger output than the one given.

For a larger shovel, the output will be correspondingly larger. For instance, a 3½-yard shovel will handle 25,000 cubic yards a month, where the 2½-yard shovel is good for only 17,000 cubic yards. The larger shovel will require 6-yard cars on standard gauge track. The 2½-yard shovel is the smallest that should be used for hard digging, such as blasted rock or shale; but for earth and sand the output will be in proportion to the size of the dipper.

The above figures may be exceeded under favourable conditions, but are those found by the author to be reliable for month after month, taking into account repairs, derailments, settling of dump and other causes for delay. Large outputs

[1] Near Pittsburg, in southeastern Kansas, more than 45 shovels are in operation stripping coal seams, 18 to 42 inches in thickness, at a depth of 40 feet or less.

have been made with the large and the medium-sized shovels on the Panama Canal work. These records are often quoted in works on excavation. It is dangerous to quote these figures without warning the reader that they represent unusual conditions which cannot be duplicated in the usual contract.

Tower Excavators. Tower excavators may be used when excavated material is deposited within 500 feet. A drag-bucket is operated between a head tower, where the greater part of the machinery is installed, and a tail tower with engine and boiler, both towers being mounted on trucks. In the case of small installations, a "dead man" may replace the tail tower. According to Massey:—

A 6-yard machine worked 75 per cent of the elapsed time, placing in the levee 40½ buckets per hour for the net working time, or one minute twenty-nine seconds average per bucket load. The average bucket load was $7\frac{1}{10}$ cubic yards.

For the total elapsed time, the machine put in the levee $30\frac{6}{10}$ buckets per hour, or one minute and fifty-eight seconds per bucket. The average haul was 350 feet.

It appears that this type of equipment is not adapted to excavating material under conditions met with in the McMurray area.

Planers and Excavators. This type of excavator consists essentially of a swinging-tower or frame, equipped with a heavy, endless link belt, provided with heavy cutting blades. The whole is mounted on wheels, moving on rails (Plates XXXIV and XXXV; Figure 8). The original planers were designed primarily for excavating clays and shales. It is claimed that as a result of subsequent modifications they are now adapted to excavate sulphur and soft ores. In the writer's opinion this type of excavator can, with certain modifications, be further adapted to the excavation of bituminous sand. Advantages claimed for this type of excavator are:—

(1) The product delivered by the excavators consists of a mixture of the different strata comprising the working-face. Material is disintegrated into small particles.

(2) Use of explosives is eliminated.

(3) Economy of operation as compared with other standard types of machines.

Planers are built to operate against exposed faces 30, 45, and 60 feet in height, and cost approximately from $15,000 to $18,000. An 80-foot planer was in operation at the plant of the Collinwood Shale Brick and Supply Company, at Cleveland, Ohio, during 1924. In 1923, a shale-planer (Plate XXXIV) operated by the Los Angeles Pressed Brick Company, near Santa Monica, Cal., was excavating approximately 500 tons of a somewhat soft clay shale per 8 hours. The crew consisted of 2 men, and power required was equivalent to approximately 50 h.p.

The standard Adel excavator (Plate XXXV) has a capacity of from 30 to 40 tons of shale per hour, depending on the nature of the material, and costs $17,000 (including driving motors), f.o.b. factory. An extra heavy excavator, adapted to working against a 50-foot face, and having a capacity of 60 to 70 tons per hour, costs $28,000. The Trinity Portland Cement Company report that with the Adel excavator, a very hard shale is being cut and delivered at the plant at a cost of about 18 cents per ton. This is said to be much lower than previous operating costs, using steam shovel and cars.

Hydraulicking. Hydraulicking methods for removal of overburden are commonly used where conditions are favourable. (Plate XXXVI). At times—as for example when bottom of overburden is approximately level—such methods must be supplemented by the use of shovels in

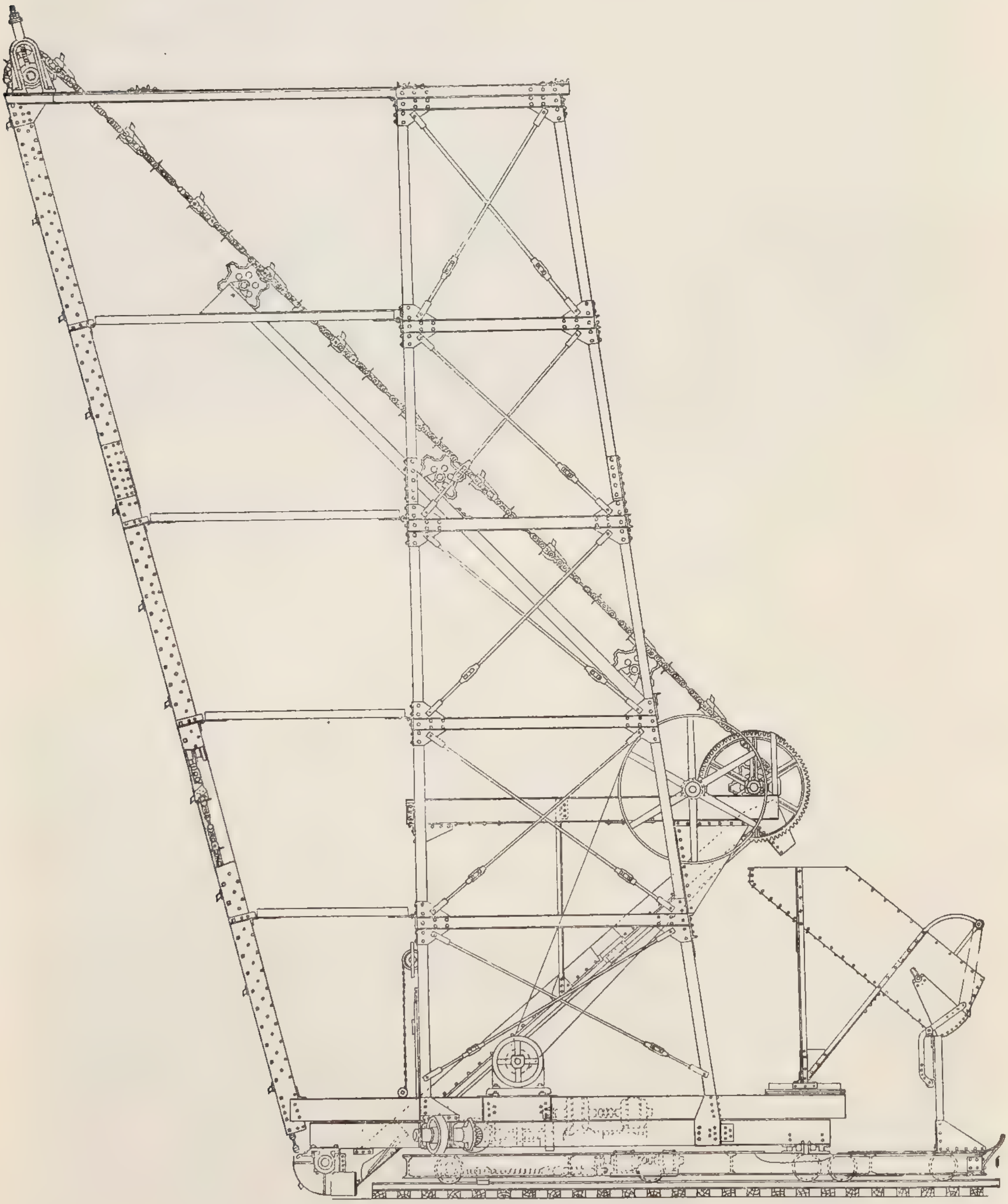


Fig. 8.—Side elevation of 45-foot Eagle shale-planer.

making the "finishing" and "clean up" cuts. They have been adopted in placer mining, removal of overburden, and in the construction of dams and cutting down hills. According to Massey:—

The grade from the toe of the face which is being washed down to the sump of the sand-pump can be as low as 4 feet in 100 feet, but it is better to allow 8 feet in 100 feet if possible. The sand-pump should be protected by screens to prevent anything over 7 inches from going to the pump. The suitable pump, for one nozzle, is one with a 12-inch suction and discharge pipe, driven by a variable-speed engine or motor so as to preserve the proper elevation of water in the sump.

A 3½-inch nozzle with a pressure at the nozzle of 100 pounds and using 3,500 gallons per minute, and a 12-inch sand-pump with suitable power and size of runner, should wash down and convey about 100 cubic yards per hour.

The amount of water used is from nine to ten times the amount of solids handled. On account of the high pressures in the pipe line, from the pressure pump to the nozzle, substantial pipe with flanges should be carefully laid and supported.

A typical example of the use of hydraulicking methods with which the writer is familiar, may be briefly referred to:—

During 1914-15, the Pittsburg Steel Ore Company[1] at Riverton, Minn., removed 60 to 80 feet of overburden, consisting of sand, clay, loam and boulders, at a minimum cost of 3 cents per cubic yard. This cost included wasting the material at a maximum distance of 400 yards. The average quantity handled was about 2,300 cubic yards per day. Water was abundant—though not under natural head.

Water under a pressure of 100 pounds was directed through 4-inch nozzles of hydraulic guns against the material to be broken down. At the property in question, the water was delivered from a nearby lake through about ¼ mile of 12-inch spiral rivetted No. 16 wrought-iron pipe.

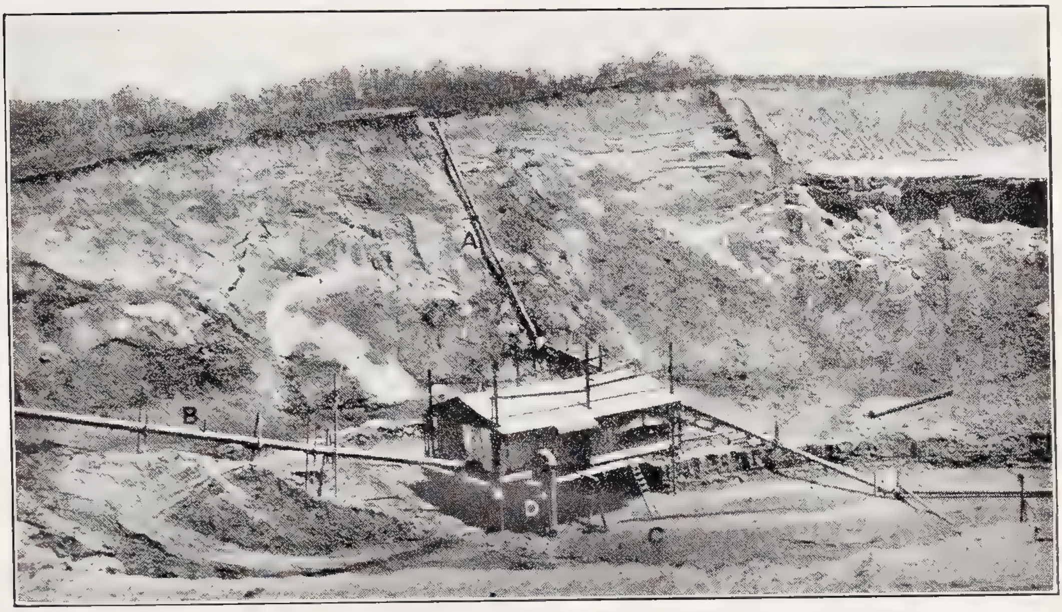
From the face, the water sluiced the sand, gravel, and boulders down a 3½ to 5 per cent slope into a shallow sump 3 to 4 feet in depth. From the sump, the material was sucked up by a heavy, specially-designed, No. 12 belt-driven Morris centrifugal sand-pump, and discharged through a line of 12-inch spiral rivetted wrought-iron pipe.

Although the pump had a 12-inch suction, and a 12-inch discharge, and although capable of handling solids up to 10 inches in actual practice, a coarse screen was used which prevented anything over 4 or 5 inches in diameter from entering the suction pipe. The pump and motor, together with a resistance to facilitate control under varying load, were housed on a heavy wooden platform, having a floor area about 16 by 30 feet. When commencing operations, a small sump was provided, either by taking advantage of some natural depression in the surface of the ground, or by actual excavation.

At the outset, 6 columns,[2] made up of short sections of heavy 3-inch casing, were driven to hard rock. Heavy clamps secured to these columns, supported wooden cradles or sills, on which the main platform rested. As excavation proceeded, the platform was lowered by chain and blocks or other suitable means; short lengths of the several columns being removed when no longer required. Finally, the platform itself reached almost to bedrock, when its position was changed to new ground, as circumstances required.

A unit such as the above, and using electric-driven pumps, requires 2 to 3 attendants only. With one gun operating continuously, 24 hours per day, against a face 30 to 60 feet high, it will break down, sluice and discharge through a pipe line, up to 70,000 cubic yards of loose earth, boulder

[1] Rapid Development on the Cayuna Range. Mining and Engineering World, August 23, 1915.
[2] It is probable that 8 columns would prove an advantage as giving greater stability and freedom from vibration.



Rowe mine, Riverton, Minnesota, showing general arrangement of plant for removal of overburden by hydraulic stripping. A, water-supply pipe to hydraulic guns; B, sump; C, discharge pipe leading from centrifugal pump; D, housed platform supported from columns driven to bedrock, and carrying centrifugal pump and motor.

Steam shovel excavating bituminous sand near Carpinteria, Cal., (1923).

Plate XXXVIII

Quarry of soft bituminous sand near Carpinteria, Cal. The bituminous sand is excavated in a series of steps, heated spades being used.

Plate XXXIX

Quarry operated by Uvalde Rock Asphalt Company, near Cline, Texas.

clay, gravel and sand per month. Indeed, the outpupt is controlled by the working-capacity of the sand-pump since a 4-inch hydraulic gun, operating under conditions such as the above, will readily break and sluice over 75,000 cubic yards per month.

Under ordinarily favourable conditions, the average cost in 1914 of breaking down, handling, and discharging the material at the end of a 1,500-foot pipe line, was well under 7 cents per cubic yard. At the Rowe mine, Riverton, Minn., a hydraulic installation, similar to that described above, was successfully handling material consisting largely of sand, with an aggregate of clay, gravel, and boulders, varying in amount up to 20 or 30 per cent of the whole. In the event of the clay forming a larger proportion, even more favourable results should be obtained.

A subsequent modification of the above method, substitutes a flat car for the usual heavy platform. The suction pipe connected with the sand-pump, overhangs that side of the car from which the material is to be taken. A small sump, not exceeding 3 feet in depth, is excavated by hand, and the gun operated against the adjacent bank, as usual.

In cases where a unit can be operated in this manner, the advantages are marked; since the entire plant can be moved to a new location several hundred feet distant, and excavation recommenced the same day. The car carries the machinery well and affords a sufficiently stable platform.

In general, advance stripping should be restricted within limits that will ensure an adequate supply of bituminous sand,—a condition which is not always favourable to use of hydraulicking methods. Moreover, hydraulicking is seriously hampered, if not entirely prevented, during severe winter weather, a restriction which does not apply to the use of shovels. Thus, a skilled crew, operating shovels or other mechanical equipment may work throughout the year, whereas the similarly skilled crew of a hydraulicking plant must be laid off, or transferred to other work, during the winter season. With a shorter operating season, the capacity of the hydraulicking unit would, of necessity, have to be greater than that of steam shovel equipment. Apparently the only satisfactory basis of comparison would be to assume a definite yardage of overburden and required tonnage of bituminous sand, and estimate costs by each of the general schemes. In certain instances, hard strata has been observed as constituting a portion of the overburden in the McMurray area. This condition would be prejudicial to the use of hydraulic methods. Approximate costs (1925) of principal items of steam shovel and of hydraulicking equipment may be summarized as follows:—

Steam shovel equipment:—

One steam shovel, 100 tons, 3 to 4 yd. dipper	$30,000
Two locomotives, 70-ton switchers	60,000
Twelve cars at $2,500	30,000
Housing and repair plant, coal and water service, etc	
Haulage and dump track	

For hydraulicking work, the following estimate appears to be reasonable:—

Power plant, 600 h.p. at $100.00 per h.p	$60,000
Clear water pumps and motors	10,000
Sand pumps and motors	8,000
Pipe valves and accessories dependent on distances and conditions	
Shops for repairs	

From the above it will be seen that first cost is adverse to the use of steam shovels. On the other hand, it is considered that the capacity of a shovel plant will be approximately double that of a hydraulicking plant.

A method commonly employed in stripping and mining coal by open-cut methods, is one involving the use of two shovels. (Plate XXXIII). The leading shovel removes the overburden, and casts it to one side, and the second shovel, following close behind, digs the coal itself. In this manner, an outcrop is sometimes followed for long distances, at very low costs. Overburden, to a thickness of 50 feet, may be readily handled by large shovels of the revolving type at a cost of approximately 15 cents per cubic yard.

As previously indicated, the problem of large-scale excavation in connexion with the bituminous sand deposits in the McMurray area, is one that can only be determined by those thoroughly familiar with such operations. Meanwhile it appears unwise to attempt to indicate with accuracy probable costs or types of equipment that should be used. It is hoped that, early in 1926, a representative of one of the largest manufacturers of excavating equipment, will visit the McMurray area.

Excavation of Bituminous Sand

Large commercial development of bituminous sand has not as yet been attempted in the McMurray area. It therefore appears desirable to refer briefly to the excavation of a somewhat similar material elsewhere.

(a) City Street Improvement Company, San Francisco, Cal.

For many years prior to 1918,[1] the above company operated a large quarry of bituminous sandstone, near Godola, Cal. The quarry is situated approximately 3 miles from and at an elevation 800 feet above rail transportation. A descending section of overburden and bituminized strata is as follows:—

Hard Monterey (Miocene) shale	40–70 feet
Bituminous sand (commercial grade)	25 "
Hard Monterey (Miocene) shale	60 "
Bituminous sand (commercial grade)	32 "
Bituminous sand (low grade)	8 "

Overburden was drilled, blasted, and removed by dragline machines.[2] The bituminous sandstone was then drilled by means of augers, churn drills being used to pass through hard strata. Holes were sprung with one-half pound of 60 per cent dynamite, and then loaded with 175 pounds of black powder. Such a charge usually broke down 280 to 300 tons of bituminous sandstone. Much of the material broken down in this manner was in masses several tons in weight, and these were subsequently further reduced in size by the use of dynamite. The rock was then transported to the railroad, and loaded on flat cars. In 1915, a mechanical tractor was substituted for horse haulage, with a reported saving on transportation costs from quarry to railroad of approximately 50 per cent. If the bituminous sandstone remained on decks of flat cars for more than 48 hours, it re-solidified to such an extent as to involve high costs for

[1] As a result of increased labour costs at the quarries, and of competition with petroleum asphalt, the production of bituminous sand in 1918 decreased from upwards of 40,000 tons to 3,260 tons, valued at $12,516.00.

[2] It is claimed that, in 1915, cost of breaking down and wasting overburden, did not exceed 9 cents per cubic yard.

unloading. Two large wooden trays, fitted with heavy lugs at the corners, were therefore placed on each car. On reaching the paving plant, these trays were lifted from the flat car by means of a light derrick, and their contents easily dumped. The reported saving over hand methods was 80 per cent.

(b) Kentucky Rock Asphalt Company, Louisville, Ky.

The Kentucky Rock Asphalt Company operates extensive quarries of bituminous sandstone at Kyrock on the Nolin river, Kentucky.

Overburden, consisting of from 2 to 3 feet of clay, underlain by hard sandstone, varies in thickness from 10 to 45 feet. The bituminous sandstone is a hard, compact rock, with which is associated approximately 7 per cent bitumen. Its thickness varies from 15 to 52 feet, with an average of from 25 to 30 feet. Sampling, by means of core drilling, precedes actual quarrying operations.

Overburden is broken down by the use of explosives, loaded by steam shovels, and train-hauled approximately 1,000 feet to disposal sites. Bituminous sand is broken down in a similar manner, loaded by cranes and derricks, and train-hauled approximately half a mile to the crushing plant. The principal equipment employed (1923) consists of 10 steam shovels, 5 cranes, 5 derricks, 12 locomotives and 90 dump cars. Daily production varies from 800 to 1,100 tons.

Crushing plant consists of primary (jaw) crushers (capacity 4,000 tons per day), which reduces the rock to sizes that will pass a 10-inch ring, and secondary crushers (capacity 1,200 tons per day), which further reduces the rock to sizes that will pass a 4-inch ring. The crushed rock is then carried by a rubber belt-conveyer, to a set of Anaconda rolls, set to 1½ inch, and thence passes to finishing rolls, where it is reduced to its constituent grains. This product passes to storage bins with a capacity of approximately 1,000 tons. Plant and equipment used represents an outlay of at least $1,500,000.

Conditions affecting transportation to the railroad are somewhat similar to those which would prevail on Athabaska river. The bituminous sand is loaded in scows, with a capacity of 250 to 400 tons, and having a draft of from 3½ to 5 feet. Stern-wheel river steamers handle tows of from 3 to 5 scows. From Kyrock, tows are taken down Nolin river, a distance of approximately 8 miles, then down Green river, a distance of approximately 40 miles, and thence up Barren river to Bowling Green, a distance of 20 miles. Minimum depth of water is 5 feet. Locking is necessary at 3 points, and each boat must be locked through separately. At Bowling Green, scows are unloaded by means of clam shells, and the material transferred by cable cars, either to railroad gondolas, or to the stock pile.

During 1923, bituminous sand was successfully excavated at Carpinteria,[1] Cal., by steam shovel (Plate XXXVII). The dipper had a capacity of ¾ cubic yard, and 5 tons was loaded in 6 minutes. No special type of dipper was used. Notwithstanding the fact that the sand contained from 16 to 24 per cent bitumen, it is stated[2] that no difficulty was experi-

[1] Of foreign deposits of bituminous sand, with which the writer is familiar, the Carpinteria material most closely resembles that found in the McMurray area.
[2] E. W. Jackson, Contracting Engineer, 1047 Vista St., Hollywood, Cal.

enced in keeping the dipper clean. The working-face was approximately 16 feet high, and overburden consisted of from 2 to 6 feet of light sandy soil. The contractor received $4.00 per cubic yard for bituminous sand loaded on trucks. Previous to the introduction of the steam shovel, the bituminous sand was excavated by hand. (Plate XXXVIII).

(c) Uvalde Rock Asphalt Company, San Antonio, Texas.

Although material quarried by this company at Uvalde consists of bituminous limestone, its operations are of interest. Operations may be said to date from 1910, although present large production did not commence until 1918. (Plate XXXIX).

Equipment at the quarries, represents an outlay of upwards of $250,000, and includes two 70-c. Bucyrus shovels and one Browning construction one-yard shovel; one Monighan dragline excavator with 100-foot boom; 3 locomotives (including a Shay 45, a Shay 75, and a 60-ton Baldwin), and a No. 10 gyratory crusher with a capacity of 100 tons per hour. There are also 16 jackhammer drills, (Plate XL, page 184), operated by compressed air, and 22 Western wheeled-scraper, dump cars for transporting rock to the crusher. Three Diesel-type engines with direct connected electric generators, and capable of developing a total of 600 h.p have recently been installed to furnish power for compressors, crushers and other machinery. A force of 125 men is employed. The company maintains an hospital, school, store, and housing accommodation.

Overburden consists principally of a soft limestone, varying in thickness up to 50 feet, but averaging 15 feet during 1924. This is broken down by 40 per cent dynamite, and removed by a dragline excavator, which takes a cut 135 feet wide.

The bituminous limestone is a very hard rock, varying in thickness from 10 to 60 feet, with an average of approximately 20 feet. It is customary to drill approximately 100 holes, (16 feet deep), at a distance of 6 feet apart, and 3 feet back from the face, the holes usually being staggered. In blasting, both 40 per cent and 60 per cent dynamite are used, half a pound of explosive breaking down approximately one ton of rock. Loading is done by steam shovels.

The average train haul to the crusher is from ¼ to ⅜ of a mile, over standard gauge track. The rock is passed through a No. 10, Austin gyratory crusher, and broken to pass a 10-inch ring. It is then ready to ship to points where it may be required. More recently two Williams pulverizers for grinding rock to sizes suitable for paving, and having a daily capacity of approximately 300 tons, have been installed. Owing to rapid compaction in the cars, distances to which the pulverized material may be shipped, are limited.

(d) Utah Copper Company.

An outstanding illustration of low mining and stripping costs, in connexion with large-scale open-cut mining of low-grade ore is presented by operations of the Utah Copper Company[1] at Bingham, near Salt Lake City, Utah.

[1] Annual Reports Utah Copper Company.

Overburden averaging 115 feet, consists of leached monzonite porphyry and quartzite. This is broken down by the use of explosives, steam shovelled into cars, and train hauled to disposal sites at distances of from ½ to 3 miles. The copper ore (copper sulphides disseminated in monzonite porphyry) is then broken down in a similar manner, and transported to the concentrators at Magna and Arthur a distance of approximately 18 miles. The scope of operations[1] is indicated by the fact that during 1923, approximately 2,517,025 cubic yards of overburden was removed at an average cost of 44·98 cents per cubic yard, and approximately 11,167,800 tons of ore was broken down at an average cost[2] of 22·38 cents per ton. Average values per ton recovered from the ore were: copper 18·18 pounds, gold 0·0065 ounce, silver 0·0628 ounce, or total values equivalent to $2·6778. Average cost of production of copper was 8·735 cents per pound. This amount is exclusive of depletion, but includes charges for depreciation, all fixed and general overhead expenses, and credits for precious metals values, and miscellaneous earnings pertaining to operations. Distributions to shareholders during 1923 amounted to $6,497,960, at the rate of $4.00 per share per annum.

Conclusion

In the opinion of the writer, either revolving shovels or a modified form of planer will be found best for excavating operations in the McMurray area. Final decision will depend on extent of proposed operations, on local topographical conditions, and on character of overburden. Definite information regarding the latter, in any individual area, can only be secured by core drilling.

[1] The maximum quantity of ore mined in any one day, was approximately 45,000 tons, together with a similar amount of overburden or an approximate total of 90,000 tons.

[2] Direct mining includes all fixed and general charges, but is exclusive of depreciation and proportion of overburden expense.

CHAPTER V

FUEL AND POWER

FUEL

If it is assumed that a process may eventually be developed for the commercial separation of bitumen from Alberta bituminous sand, the question of a fuel supply at once becomes of importance. This will be the case particularly if an extensive use of heated water appears desirable.

The value of a fuel for steam-raising purposes cannot be expressed by a single figure, since the fuel may be required for raising steam under very diverse circumstances and conditions, but the most comprehensive measure of its value is the ratio of the weight of steam produced to the weight of fuel burned to produce it.

This ratio depends upon the calorific value of the fuel, the conditions prevailing at the time it is burned, and the construction and design of the apparatus for burning the fuel and absorbing heat for steam generation.

The calorific value of a fuel represents its total energy, and is usually expressed in British Thermal Units[1] per pound, or calories per gramme. This energy is liberated by combustion, and its quantity is determined by burning a known weight of the fuel in pure oxygen in a calorimeter, and measuring the heat absorbed in cooling the products of combustion to the initial temperature of the fuel and oxygen.

When a fuel is to be used for steam generation it is desired to evaporate as large a quantity of water as possible per unit quantity of fuel. It is impossible, under commercial conditions, to use all the heat of the fuel for this purpose, since, in order to accomplish this, it would be necessary to burn the fuel completely, and to utilize all the heat generated by cooling the products of combustion, excess air, and ash, to the temperature prevailing before combustion took place.

When burned under a boiler, a portion of the heat of the fuel is dissipated in the following forms of unused energy:—

1. Unburnt solid combustible (approximately 10 per cent).
2. Unburnt gaseous combustible (probably small, say 1 per cent).
3. Heat carried off in the chimney gases (approximately 20 per cent).
4. Heat lost by radiation, and removal of hot clinker and ash (say 8 per cent).

When using a very low grade fuel,[2] the losses will be much greater for every 100 heat units charged to the furnace. Assuming, however, equal efficiency, accepting efficiency of furnace and setting as 61 per cent, and a boiler efficiency of 60 per cent, it follows that the overall efficiency of the installation would be approximately 36 per cent.

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[1] The unit of heat used in this report is the mean British Thermal Unit, or B.T.U.
[2] For articles on combustion of refuse (low calorific value materials) see Jour. of Soc. of Chem. Ind., Vol. 23, p. 383; Metallurgical and Chemical Engineer, p. 229, Feb. 15, 1917.

It would be possible, by adding to the heating surface, and changing the path of the gases over this surface, to increase the efficiency of the boiler proper to as high as say 80 per cent, thus increasing the overall efficiency to 49 per cent. Such a change would obviously involve a higher expenditure for the plant. An efficiency of 49 per cent would correspond to an evaporation of about one pound of water per pound of bituminous sand of a calorific value of 2,400 B.T.U.

It must be remembered that a portion of this steam will be required for operating the auxiliary machinery, such as a blower or fan for the blast, a stoker, if one be used, and the feed-pump.

If a furnace of the forced-draft type be used, the power for the fan will be the principal auxiliary to be considered.

Four potential sources from which fuel for use in the McMurray area may be secured may be briefly referred to.

(*a*) Seams of Lignite near McMurray

For many years past, claims have been made by various persons regarding the occurrence of coal seams in the McMurray area. Two of the more important of the reported seams were, therefore, investigated and samples procured in 1914. Proximate analyses,[1] by fast coking, are given below, and are, as far as the writer is aware, the first definite information regarding the character of the coal in this area. The sample from McKay is from an outcrop just above June water level of Athabaska river, and almost due east from the Roman Catholic mission house. The other sample is from a point on the Christina river, approximately 5½ miles from the mouth. This outcrop occurs in the north bank and is just above June water level. Both seams are, therefore, at or near the base of the McMurray formation.

	McKay	Christina river
Water	17·32 per cent	19·67 per cent
Volatile combustible	37·96 "	35·10 "
Fixed carbon	35·79 "	34·27 "
Ash	8·93 "	10·96 "
	100·00	100·00
Fuel ratio (fixed carbon/volatile matter)	0·94	0·97

It was not practicable to determine the actual extent of the seams, as this would have involved a considerable amount of excavation. It appears, however, that seams of lignite in the McMurray area are in the form of local lenses associated with the bituminous sand, and that they are of doubtful commercial value.

Along the Athabaska, above and below Grand rapids, a seam of lignite outcrops for several miles, and at a number of points may be readily seen from the middle of the river. In returning to Athabaska in the fall of 1914, an assistant, the late Mr. C. R. Ritson made a hurried examination of the occurrence.

According to Mr. Ritson, the seam lies just above the Grand Rapids sandstone, and varies in thickness from 3 to 15 feet. Owing to frequent and extensive clay and rock slides a complete examination would necessitate considerable excavation.

[1] Analyses by Chemical Division, Mines Branch, Department of Mines.

It appears that the seam contains a large percentage of impurities, consisting principally of clay partings. Bands of fairly clean lignite from 1 to 2½ feet in thickness were, however, noted.

A sample taken from one of these bands, and at a depth of 4 feet from the face gave the following analysis:[1]

Moisture	3·2 per cent
Ash	75·8 "
Volatile matter	13·8 "
Fixed carbon (by difference)	7·2 "

More recently (July 1924) a tunnel was driven, by A. von Hammerstein, for more than 20 feet on a seam of lignite outcropping on the east bank of Athabaska river (sec. 19, tp. 91, range 9).

An analysis[2] of a representative sample taken by the writer is as follows:—

Loss on air-drying	2·0 per cent
Proximate analysis—	
Moisture	16·2 "
Ash	7·9 "
Volatile matter	36·2 "
Fixed carbon (by difference)	39·7 "
B.T.U. per pound	9360 "
Fuel ratio (fixed carbon/volatile matter)	1·10 "
Coking properties	Non-coking

The maximum thickness of the seam was 28 inches.

As is usual with coal seams in the McMurray area, roof and floor were unstable, and in spite of fairly secure timbering, the tunnel collapsed within a comparatively short time.

(*b*) Natural Gas

Gas sands have a wide distribution in northern Alberta. At present, productive wells nearest to McMurray are those at Lower Pelican rapids. In October, 1922, two of these wells had an estimated combined capacity[3] of about 6,000,000 cubic feet per 24 hours and are approximately 90 miles from McMurray in a direct line. At the mouth of Little Buffalo river, 50 miles from McMurray in a direct line, there is a strong seepage of natural gas. No development work has been attempted at this point, nor is anything known regarding the character of the gas itself. The writer considers that intelligent prospecting for natural gas at points a few miles south of McMurray would have a reasonable chance of meeting with success. A well sunk in 1907 by A. von Hammerstein, near Tar island (sec. 18, tp. 92, range 9, W. of the 4th mer.), approximately 20 miles north of McMurray, gave a small flow of gas. More recently (1916) some gas was struck at a depth of 325 feet in a well drilled in S.W. ¼ sec. 33, township 87, range 7, west of the 4th meridian, and a small flow was also met with at a depth of 465 feet in a well located in S.W. ¼ sec. 27, tp. 85, range 7, west of the 4th meridian.

[1] Analysis by Fuel Testing Laboratories, Mines Branch.
[2] Analysis by Fuel Testing Laboratories, Mines Branch.
[3] Estimated by S. E. Slipper.

(c) Lignite Coal. ***(From points outside the McMurray district)***

This fuel can be purchased at the mine in Edmonton (January, 1925) for about $3 per ton. The rail haul from Edmonton to McMurray would be slightly less than 300 miles, and the freight on Edmonton coal would not be less than $2.25 per ton. This coal has an average heating value of about 9,000 B.T.U. per pound. Coals from certain other points in Alberta have somewhat higher heating values, which might more than compensate for the longer rail haul.

(d) Crude Bituminous Sand

The possibility of burning crude bituminous sand under boilers has been suggested on several occasions. Although there seems to be little probability that the material can be commercially utilized in this manner, the following brief statement may be of interest.

It is stated[1] that about 1891 an attempt was made to burn a 14 per cent crude bituminous sand, at the separation plant operated by the Alcatraz Asphalt Co., at Carpinteria. No special grates were used, hand-stoking being depended on altogether.

It is stated that the capacity of the boilers heated by bituminous sand approximated 160 h.p. At that time coal (12,000 B.T.U.) was brought from Australia, and sold in California at $17 per ton. The principal drawback in burning bituminous sand appears to have been in stirring the bed of fuel, which involved very arduous work. Labour costs in handling such a large bulk of fuel and of ash were also excessive.

In considering the possible use of bituminous sand as fuel under stationary boilers at McMurray, the following statement has a direct bearing:—

One pound of 14 per cent bituminous sand has a heating value of 2,240 B.T.U.

One pound of average Alberta lignite (Edmonton area) has a heating value of 9,000 B.T.U.

Considering the calorific value of Alberta lignite, it appears that on the basis of fuel cost alone, bituminous sand has an advantage as a solid fuel under boilers. But, if we assume a successful commercial separation process, which will produce bitumen at not over $15 per ton refined, it would be more economical of raw material to burn 9,000 B.T.U. lignite at $5.25 per ton, than to burn crude bituminous sand of an equivalent heating value.

Assuming, however, that in view of the large tonnage of bituminous sand available in northern Alberta, it might become desirable to burn such material, the question of the method of burning at once arises. Two methods may be briefly referred to:—

By Burning the Bituminous Sand on some Type of Grate. Two types of grate may be mentioned, namely the underfeed stoker and the overfeed chain-grate stoker. Of these the former cannot be seriously considered. The latter, however, may have some slight possibilities.

[1] Geo. Westwick, formerly mechanical foreman with the Alcatraz Asphalt Co., at Carpinteria, Cal.

Of the overfeed chain-grate stokers, two makes have been considered, namely the Playford and the Green chain-grate. The merits and adaptability of these two grates for burning bituminous sand were considered by representatives of the two companies, and the conclusion reached was that their standard grate, without modifications, would not handle the material. Each representative stated that, in a modified form, their grates might prove successful, but that this was by no means certain. Each considered that a trial run would be the only means of definitely deciding the matter.

The Babcock and Wilcox Company have installed grates at the University of Alberta at Edmonton.

In 1915, the Green Company installed two of their chain stokers in Edmonton, Alberta, and it has been suggested (1916) that arrangements be made to try a shipment of bituminous sand on one of these grates.

The suggestion, if acted upon, might demonstrate that the link-grate, in its present form, is not adapted to burning bituminous sand. On the other hand, such a test would undoubtedly furnish some definite data of value. The results might be conclusive against the use of a moving-grate. If not, they might indicate possible modifications for further consideration.

The calorific value stated above (2,240 B.T.U.) is deduced from the calorific value of bitumen recovered from the crude bituminous sand by destructive distillation. This value is, however, believed to be low. An analysis of another sample of approximately the same grade of crude material showed the following:—

Volatile matter	14·82 per cent
Fixed carbon	1·70 "
Ash (quartz sand)	83·48 "

The sand, as analysed, has a calorific value of 2,710 B.T.U. The ignition point, 520° F., was determined in a manner analogous to an open flash-point determination.

An analysis of the sand showed the following:—

Silica	96·28 per cent
Iron oxide and alumina	2·60 "
Calcium carbonate	0·78 "
Magnesia	0·15 "
Undetermined	0·19 "

In the foregoing the iron oxide and alumina are reported together. Other determinations have shown, however, that the sand contains less than 0·5 per cent iron. The temperature of fusion would approximate that of a high-grade silica brick and consequently is above the temperature of fusion of the majority of ashes in coal. In burning, each individual piece or lump shows a tendency to mat, but there does not seem to be much tendency for the various lumps to fuse together, a condition that would appear favourable to the use of a chain-grate stoker.

The average chain-grate stoker burns 20 pounds of coal per square foot of grate surface per hour. Assuming 6 pounds of bituminous sand as the equivalent of one pound of coal, and allowing 20 pounds of bituminous sand per square foot of grate surface, the use of bituminous sand would be considered as the equivalent of about 1⅓ pound of coal per square foot of grate surface. This would be altogether insufficient.

Volatilization of the Contained Bitumen. Further investigation might indicate the possibility of volatilizing the bituminous sand without passing the sand through the fire at all. If used in this manner, however, the thermal efficiency would probably be low owing to the fact that much fixed carbon would be left in the residue.

It may be added that at the present time, apart from certain refuse destructors, no steam generator uses fuel of so low a calorific value as the bituminous sand. Indeed, the average ash and clinker removed from the boiler room of a power-house contains more combustible matter.

A sample of the bituminous sand was also submitted to Messrs. Tate-Jones and Company, engineers and manufacturers of fuel-oil and natural gas-burning installations. Mr. W. C. Buell, of the above company, examined this sample and his conclusions may be briefly stated as follows:—

An attempt was made to liquefy the crude material so that it might be burned through some type of oil or tar burner. It appears, however, impracticable to accomplish this. At temperatures up to 1,400° F., the material will not liquefy, but, at a lower temperature, if exposed to air, the material will burn; thus, combustion precedes liquefaction. Mechanically, the wear on the burners would be prohibitive.

From present information, therefore, better results would be secured by retorting the crude bituminous sand. The crude petroleum so derived could be passed through a topping-plant and the product above 150° C. utilized by means of fuel-oil burners.

The crude oil (assuming a sp. gr. of 22° Bé.) distilled from the bituminous sand has a calorific value of 17,800 B.T.U. per pound. The fractions above 150° C. (19° Bé.) has a calorific value of 16,560 B.T.U. per pound, or approximately 155,500 B.T.U. per gallon. The relative cost (1916) of a gas-burning installation would be about as follows: The cost of gas burners only would be about $500 and the cost of a producer would be $4,000 to $7,500 depending on type and size. An oil-burning installation, capable of developing 400 boiler horse-power including pumps, burners, oil heater, strainers, gauges, relief valves, and other auxiliary equipment but not installation, would cost at present prices approximately $800 to $1,000.

A sample of the bituminous sand was also submitted to the Dwight and Lloyd Sintering Co., in 1916. The following report was received:—

Referring to the bituminous sand sent us recently at the request of Mr. S. C. Ells, I beg to advise you that I have been unable to obtain any satisfactory results in my attempts to burn this material. My observations lead me to the conclusion that the trouble lies in the fact that the largest part of the fuel contained in the bitumen consists of volatiles, which are rapidly driven off under the influence of heat. The remaining portion of the carbon, which I will for the sake of convenience call coke, is too small to keep up the combustion of the material in our process. The volatiles are simply driven off as unburnt gas. As a result of these experiments, I believe that there would be a possibility of using this bituminous sand, mixing it with a small proportion of fine coal, coke or possibly even sawdust, and putting it into a specially designed form of gas producer. The volatiles could be driven off as a rich gas, to be then easily burned in any convenient manner under boilers or in furnaces.

Prior to 1911, Mr. A. H. Lepley, mechanical superintendent of the Atlantic Refining Company, Philadelphia, designed a "straightaway" furnace for the recovery of copper oxide used in the desulphurization of petroleum. In this process the copper oxide, much of which will pass a 100-mesh screen, is agitated with crude petroleum. In order to recover the oxide, the oxide-petroleum mixture is pressed to remove as much petroleum as possible and the residual cake, carrying as high as 80 per cent ash, is burned to remove the last traces of petroleum. The pressed coke was fed from the press into the charging-floor and thence hand-fired onto the moving grate. The grate moved at a rate of about 10 feet per minute and the fuel bed was about 6 inches thick. It is claimed that steam was successfully raised in this manner, although at the Philadelphia works the use of the "straightaway" grates has been discontinued. Grates of this type were, however, in use by the Imperial Oil Company at Sarnia, in 1916, and the company has offered to furnish any information they may have regarding results that have been obtained.

In view of the above, the following statement regarding the efficiency of high ash fuels is of direct interest.

In 1906 a series of tests was made at a power-house of the Chicago Edison Company under the supervision of Mr. A. Bement. In general these tests were made to determine the effect of varying percentages of ash and of different grades of fineness upon the value of the coal. In considering the possible fuel value of bituminous sand which is high in ash and very finely divided, the results of the above work are of interest.

The apparatus employed in the researches to be considered consisted of two Babcock and Wilcox boilers, one being fourteen tubes high and eighteen wide, of approximately 5,000 square feet of heating surface, fitted with a chain-grate stoker of 75 square feet area, which discharged the gases of the fire from under an ignition arch 5 feet long, immediately among the tubes of the boiler; this boiler was also fitted with a Babcock and Wilcox superheater having an approximate area of 1,000 square feet. The other apparatus employed in one of the series of tests differs only in sizes; its boiler was twelve tubes high and sixteen wide, contained 4,000 square feet of heating surface, provided with a superheater and served with a chain-grate stoker of 66 square feet area.

To determine the effect of ash upon the value of fuel, a series of tests was conducted upon a large and uniform lot of coal. A portion of this sample was carefully analysed and tested in its natural condition as received from the mine. Another portion of the original coal was then taken and into it mixed a known percentage of ash. This gave a quality of coal similar to what was tested first, but containing more ash. This was tested. On the following day another lot was tested with a greater per cent of ash added, and so on. The first test was made with coal containing something less than 10 per cent ash, and successive tests with increasing amounts. When the ash content had been increased to 40 per cent, the coal would heat the water up to the boiling-point, but it would not produce enough heat to make steam. Therefore, coal containing 40 per cent of ash was absolutely valueless.

The object of these tests, as stated before, was to determine upon some simple rules or tabulation to fix the commercial value of coals. For

this purpose records of various tested samples, their boiler efficiency values, together with the percentages which would go through a $\frac{1}{4}$-inch screen were used.

The calorific value of coals used in the tests averaged about 12,000 B.T.U. for moist coal and 13,000 B.T.U. for dry coal. The value of the pure coal—i.e. free from ash—ranged from 13,800 to 14,500 B.T.U. Coal carrying 40 per cent ash gives zero efficiency and this corresponds to a fuel with a calorific value of approximately 5,600 B.T.U. or more than double the calorific value of 14 per cent bituminous sand.

It need scarcely be added that developments subsequent to the tests referred to above, have shown that the ash in fuel cannot be increased very materially beyond 40 per cent.

From the above it would appear that the practicability of using crude bituminous sand as a fuel for steam-raising purposes cannot be proved or disproved by purely theoretical considerations. To definitely settle the question, practical experimental investigation would be necessary. The successful utilization of such a material in this way is, however, extremely doubtful. Recognizing this fact, the writer some years ago recommended that steps be taken to discover some source of cheap fuel, preferably natural gas, in the area immediately adjacent to McMurray.

WATER POWERS

Reference to water powers available in the McMurray area has been made from time to time in various publications. The most recent authoritative statement appears in "Water Resources, No. 16," issued in 1916 by the Dominion Water Power Branch of the Department of the Interior. The statement reads in part as follows:—

> At Grand rapids, where the (Athabaska) river divides in two about an island, there is a drop of 50 feet, but the whole of this is not available for utilization, the upper portion only, or Big Grand rapids, being the part that would be developed.
>
> The measured water flows have been quite disappointing, the minimum flow being 2,358 cubic feet per second, while a maximum record was 61,621 cubic feet, and there were in addition evidences of a flood flow of 110,000 cubic feet per second. The low flow occurs in winter, and to offset this effect the Water Power Branch Engineers have sought for suitable storage sites available for the increase of the winter supply. After examination of those lakes, known to be of appreciable extent, including Jasper and Brûlé lakes, Lac la Biche, and Lesser Slave lake, it was found that but small opportunity existed for the economical creation of storage.
>
> With a flow of 2,300 cubic feet per second and the head of 45 feet obtainable at Grand rapids, a turbine output of 9,410 h.p. would be available, but at a construction cost of over $5,000,000, involving, as it does, a steam auxiliary plant and a transmission line of 200 miles in length to the city of Edmonton.

McMurray is approximately 80 miles distant from Grand rapids.

The following statements are furnished by the Dominion Water Powers and Reclamation Service, Department of the Interior.

> In the stretch of river from the foot of Grand rapids to (Fort) McMurray, a distance of 75 miles, there is a drop of about 375 feet. It is thought possible to develop this total head at certain advantageous points as the reach contains many rapids where rock outcrops on either bank. These rapids have not been investigated so that detailed information is not available.
>
> Based on an estimated ordinary minimum flow of 2,300 c.f.s. the power available, using the total descent in this reach of river, would be 78,400 h.p. and with a flow of 8,000 c.f.s ordinarily available for six months of the year the power output would be 272,700 h.p.

CLEARWATER RIVER

The estimated drainage area of the Clearwater river above Cascade rapids is 5,000 square miles. The only information available as to the general run-off conditions of this river is a discharge measurement taken in September, 1912, immediately below Cascade rapids, the discharge being 2,241 c.f.s. Undoubtedly the minimum flow occurs during the winter months, while the maximum probably occurs between April and July, depending largely on weather conditions. From the data available, the ordinary minimum flow has been estimated at 370 c.f.s. and the ordinary six-month flow at 1,120 c.f.s.

No information is available as to storage or ice conditions.

Power Available

No power surveys have been made on this river and the power possibilities listed below are based on heads which represent the actual drop in the rapids and falls.

Power Site 7CD₃—Whitemud rapids.—Whitemud rapids is located about four miles west of the interprovincial boundary separating Alberta and Saskatchewan. There is a descent of 40·6 feet in a distance of a quarter of a mile. The banks are from 50 to 75 feet high throughout this section and are composed of limestone. The channel is divided by an island in midstream affording a favourable dam section. A natural head of 41 feet is obtainable but further investigation might reveal that this head could be considerably increased by flooding out several rapids above.

The power output based on a head of 41 feet at 80 per cent efficiency is 1,380 h.p. for ordinary minimum flow, and 4,175 h.p. for ordinary six-month flow.

Power Site 7CD₂—Aux Pins rapids.—This site is about four miles below Whitemud rapids. The river passes through a rocky channel for three-quarters of a mile between canyon-like banks 150 feet high, the drop in this section being 21 feet. The available head has been placed at 21 feet although it is probable that physical features would warrant the development of a much greater head.

The estimated power available at 80 per cent efficiency is 713 h.p. for ordinary minimum flow and 2,138 h.p. for ordinary six-month flow.

Power Site 7CD₁—Cascade, Le Bon and Bigstone rapids.—These three rapids are situated in a stretch of the river some five miles in length and about nineteen miles below Methy portage. Bigstone rapid has a descent of 6·5 feet in a third of a mile. The banks are low and the width of river is about 300 feet. Le Bon rapids is situated about one-half mile below Bigstone rapid and has a descent of 31 feet in one and a half miles. The river varies from 200 to 400 feet in width and contains a few islands. Cascade rapids is about one mile below Le Bon rapids. The drop is 16 feet in a distance of one mile. The lower portion of the rapid is 400 feet wide with low banks while the upper portion narrows to 200 feet with high rocky banks.

By concentrating the total descent in the three rapids at Cascade rapids a head of 54 feet might be obtained. The power available at 80 per cent efficiency for minimum flow would be 1,830 h.p. and for ordinary six-month flow 5,500 h.p.

Table 1 summarizes the principal features of the possible power sites on the Clearwater river.

Table 1—Clearwater River—Estimated Flow and Power

Site	Index No.	Head in feet	Flow in second-feet		H.P. at 80 p.c. eff.	
			Ordinary minimum	Ordinary six-month flow	Ordinary minimum	Ordinary six-month flow
Whitemud rapids	$7CD_3$	41	370	1,120	1,380	4,175
Aux Pins	$7CD_2$	21	370	1,120	713	2,138
Cascade rapids	$7CD_1$	54	370	1,120	1,830	5,500
Totals					3,923	11,813

CHAPTER VI

REVIEW OF PROCESSES DESIGNED FOR RECOVERY OF HYDROCARBONS ASSOCIATED WITH BITUMINOUS SAND

In 1913, the writer indicated that, in any attempt to ship crude bituminous sand, freight charges would adversely affect large commercial development. This view is now generally accepted, and requires no comment. For many years, prior to 1913, however, the obvious desirability of developing a successful process for commercial recovery of hydrocarbons associated with bituminous sand had been fully recognized in foreign countries, and considerable study had been given to the problem. In the United States, active interest in the matter ceased to a great extent about the year 1905, owing largely to rapidly increasing production of well petroleum, together with marked modification in refinery practice. More recently, changing conditions have again appeared to warrant further investigation of the recovery problem.

In refining asphalt purity of product is important, since this affects its spreading capacity, as well as packing and transportation charges. The nature and relations of petrolene and asphaltene, must also be considered, since these govern the quality and physical properties of the asphalt.[1] For paving purposes especially the nature of petrolene is of importance. Petrolene and asphaltene are not fixed bodies, but mixtures of various hydrocarbons, each having individual properties. The aggregate composition may answer to the required formula of what is known as asphaltene and petrolene, and yet differ sufficiently in physical properties to render an asphalt unfit for paving purposes.

Regarding the history of separation or extraction prior to 1913, written records are, for the most part, incomplete or entirely lacking. In nearly every instance, however, either heated water, or some solvent, was adopted as the active principle. Of upwards of a dozen attempts at commercial separation made prior to 1913, and with which the writer is familiar, the principal remaining evidence consists in a considerable number of disappointed investors, and in ruins of abandoned incomplete plants. Probably the two most ambitious attemps resulted in the construction of separation plants at Carpinteria and at Sisquoc, in California. The former is said to have represented an expenditure of approximately $300,000, and was abandoned prior to 1899. The latter, which was abandoned about 1901, is said to have involved a financial outlay of approximately $1,000,000.

In referring to the history of separation prior to 1913, four general methods may be briefly mentioned.[2]

(a) Separation by use of Heated Water. This is one of the oldest methods, and was practised in Europe and in America for a number of

[1] Speilmann, P. E.: Bituminous Substances; Scientific Progress of Practical Importance during the Last Fifteen Years, 1925.

[2] Mineral Industry, 1899.

years. In Europe the crude bituminous sand was crushed and placed in kettles, 3 to 4 feet in diameter, and about half-filled with water. These were arranged in batteries of four to six kettles, in such a manner that the contents of any or all could be brought to the boiling-point. Bitumen—known in Europe as 'goudron mineral'—recovered in this way contained varying percentages of water and mineral matter, and was again heated until the water was evaporated, and other impurities partly settled out.

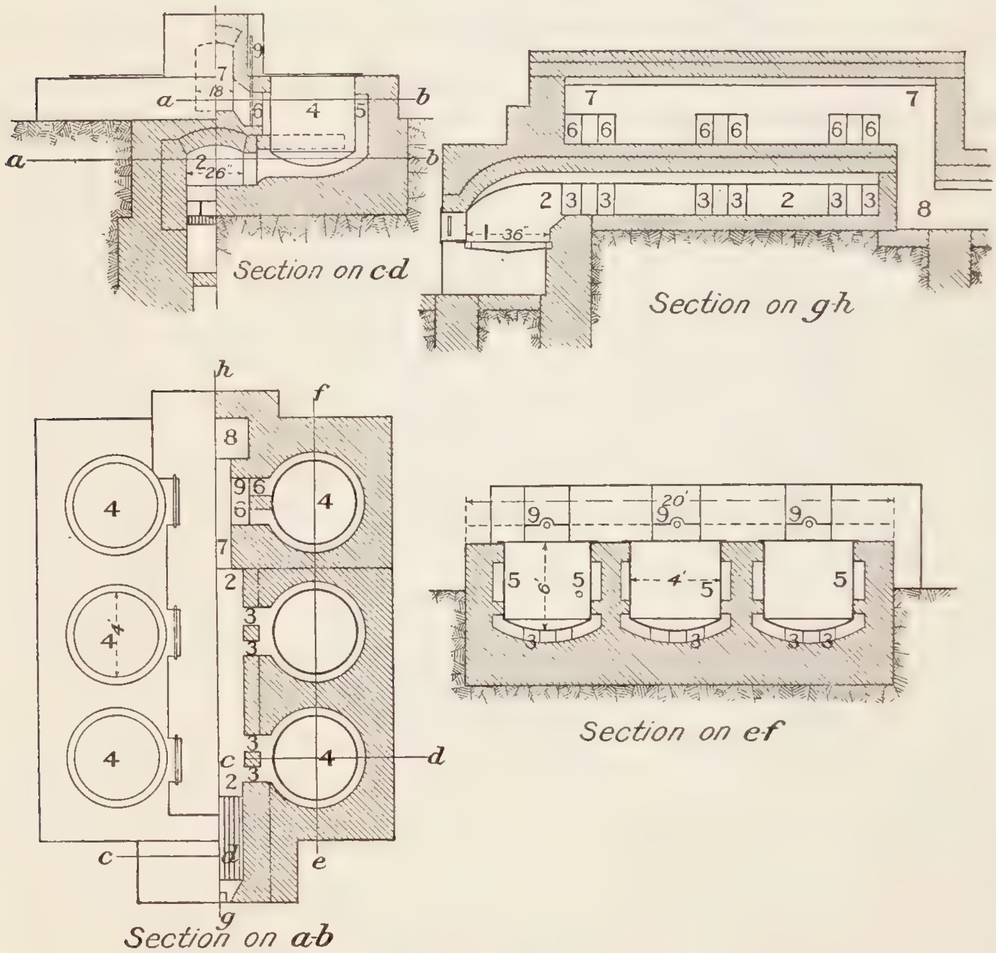

Fig. 9.—Battery of kettles for separation of bitumen from bituminous sand.

The general design of furnace, and arrangement of a battery of six kettles, is shown in Figure 9. Heat from grate (1) passed through flue (2), and openings (3) below the kettles (4); thence through flues (5), and openings (6), to flue (7), which was directly above flue (2); from (7) the gases passed through (8) to the chimney. Openings (6) are closed by means of dampers (9); thereby regulating the temperature of any of the kettles.

In certain instances, steam heat was used in place of the fire grate, and certain reagents added to the water in order to hasten separation.

(b) Refining by Liquation. Certain of the heavier bitumens, such as that from Trinidad lake—with which is associated very finely divided mineral matter—are not amenable to hot water treatment. These

bitumens (or asphalts) are therefore melted, the water evaporated off, and the heavier impurities allowed to settle out. Vein asphalt mined at La Patera, Cal., contained approximately 85 per cent bitumen, 9 per cent infusorial earth, and 6 per cent water. This was heated to about 350° F., and the water evaporated. When the material contains a high percentage of coarse mineral matter the refining may be accomplished in two stages.

(c) Separation by Liquation. For recovery of bitumen from bituminous limestones,[1] several methods have been employed. The earliest process consisted in subjecting the rock to a temperature higher than the melting-point of the associated bitumen, which is collected as it drains from the retort. As an example, operations by the Neuchatel Asphalte Company, near San Valentino in the province of Chieti, Italy, may be cited. Cylindrical retorts of light (15 mm.) sheet iron known as "calderoni", and very similar to those employed in Sicily for the recovery of sulphur, are used. The length of each cylinder is about 2 metres and the diameter about 65 centimetres. The cylinders are set in pairs in brickwork, and are inclined at an angle of about 20 degrees. (Figure 10).

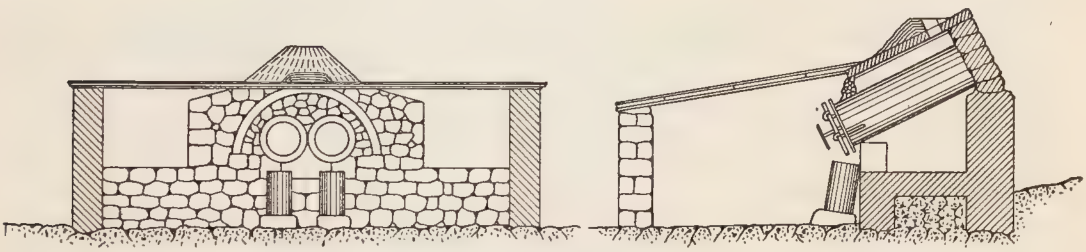

Fig. 10.—Retorts used for recovery of bitumen from refractory bituminous limestone.

The cylinders are charged four times in 24 hours, the charge for each cylinder being about 1,100 pounds of bituminous limestone (asphalte).

The crude rock contains an average of 10 per cent bitumen, of which less than 50 per cent is actually recovered. Small fragments of the rock tend to retard extraction, lumps 6 to 8 inches in diameter giving best results. The smaller pieces, together with a certain percentage of spent rock, are used as fuel, and burn with a long smoky flame. The free bitumen collects in the lower ends of the retorts, and is drawn off through a small opening. The largest number of retorts operated by the company at any one time was 24. Prior to 1914, the approximate annual production of pure bitumen by the above method was 700 tons at a cost of approximately 200 lira[2] per ton.

(d) Extraction by the Use of Petroleum Distillate. In selecting a solvent, it should be remembered that both petrolene and asphaltene are completely soluble in carbon bisulphide. Petroleum naphtha of 85° Bé. at room temperature dissolves petrolene in all proportions leaving asphaltenes as an insoluble residue.

[1] Known in France as calcaire bitumineuse or asphalte, and in Germany as asphalte Kalkstein or asphalstein.
[2] Under normal exchange, 1 lira is equivalent to approximately 20 cents.

A type of separation apparatus, in which petroleum naphtha was used as the solvent, was designed about 1892 by the late H. A. Frasch. Detailed reference to this will be found in a subsequent part of this chapter dealing with operations of the Uvalde Rock Asphalt Company at Cline, Texas.

(e) Extraction by Means of Carbon Bisulphide. The use of carbon bisulphide has the advantage that it may be used at atmospheric temperature. Extraction would also be affected more rapidly, and were it not for its greater volatility and inflammability, carbon bisulphide might be preferable to petroleum naphtha.

It appears that the use of carbon bisulphide involves approximately the same amount of labour, and about 10 per cent less steam, although a plant of equal dimensions would probably have a larger throughput capacity than if petroleum naphtha were used. On the other hand, constituents of the bitumen cannot be adjusted, as is the case when petroleum naphtha is used. Moreover, carbon bisulphide is more expensive, and the loss of solvent would doubtless be greater as it is capable of combining chemically with certain constituents that might be contained in the bitumen.

Prior to 1913, treatment of bituminous sand—and of bituminous limestone—was directed primarily toward production of a bitumen, more or less unaltered from its original consistency. During more recent years, commencing about 1917, effort has also been directed toward recovery of the original bitumen, either in the form of crude petroleum, or of various petroleum fractions.

EUROPE[1] AND AFRICA[2]

At various localities in Europe, deposits of bituminous sand, (sable bitumineuse) occur, notably in the province of Rome in Italy[3]; near Pont-du-Chateau (Seyssel) in France[4]; at Pechelbronn in Alsace[5]; near Maestu and elsewhere in Spain; near Tartaros[6] in Hungary; in Albania[7]; near Matitza in Rumania, and in the Gigulev hills and elsewhere in Russia. Attempts at commercial separation in these localities have depended chiefly on the use of water, heated at various temperatures up to 212° F. At Pyremont and in Italy, the use of carbon bisulphide was also attempted but without success.

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[1] Gmelin: Handbook of Chemistry. Vol. 17. (1866). Kohler, H.: Chemistry and Technology of Natural and Artificial Asphalts (1904). Dammer; Handbuch der Chemischen Technologie; vol. 3 (1896). Malo, Leon; L'Asphalte (1898).

[2] Petroleum Leitschrift; p. 1070. 1907-8; pp. 641-44, June, 1915.

[3] Ascione, Ernesto; L'Industria dell' Asphalto. Milan, 1913.

[4] Malo, Leon; Note sur l'Asphalte; son origin, sa preparation, ses applications suivi de divers documents sur la matiere (Paris, 1863).

[5] Historique de Pechelbronn 1498-1918, par Paul de Chambrier, (Ancien Directeur des Mines et Raffineries de Pechelbronn).

Etude Economique sur l'Exploitation du Petrole par Drainage Souterrain, par Paul de Chambrier. (Ingenieur-Conseil Pechelbronn.) Extrait de Chimie & Industrie, May 1923.

Technique de l'Exploitation Miniere a Pechelbronn, par M. Schlumberger, (Ingenieur en Chef des Mines), Extrait de Chimie & Industrie, May 1923.

Camsell, Chas. and Buisson, A. Recovery of Petroleum by Shafts and Galleries at Pechelbronn, Alsace, France, and at Wietze, Hanover, Germany. Mines Branch Memorandum Series, No. 10, 1924.

[6] Kohler, H., Chemistry and Technology of Natural and Artificial Asphalts.

[7] Bouganville; Voyage dans la Grece; t. I. p. 271 de Launay; Traite de Gites mineraux; 1913. Annales des Mines: Vol. 4, 1914, Sec. 10. Coquand, H. Societe Geologigue de France, 1868.

At one time in Russia, separation of bitumen from bituminous sand attained some importance, and in 1895, according to H. K. Lipinski,[1] the production of asphalt mastic was approximately 27,000 short tons. In the production of this mastic, 7,000 short tons of bitumen was required, of which the greater part was originally imported from foreign countries. Eventually local deposits of bituminous sand, notably in the Gigulev hills near the Volga, were developed as a part source of supply.

The bituminous sand occurs as isolated pockets containing from a few hundredweight to 75 tons, and the content in bitumen is approximately 17 per cent. In the larger pockets, lean strata of harder sand and of conglomerate are frequently interbedded with the bituminous sand. As is the case in the McMurray district, the bituminous sand rests on Devonian limestone.

The bitumen was separated from the bituminous sand in two stages, by the use of boiling water. In some instances, sulphuric acid was added to the water to hasten separation. On being introduced into the first series of kettles, a portion of the sand settled out, and a product—approximately 35 per cent pure—was skimmed from the surface of the water by means of perforated ladles. A second and similar treatment gave a bitumen approximately 60 per cent pure, with which was associated 40 per cent of water and silt. It is said that further purification could only be secured at a prohibitive cost.

It was found that certain varieties of bituminous sand did not disintegrate readily in heated water, and required treatment by some solvent, such as carbon bisulphide or a petroleum distillate.

The most important recognized deposits of bituminous sand as yet found in Africa occur in Nigeria. In connexion with attempted commercial separation, boiling water was adopted as the separation medium. It appears that in part, inadequate transportation facilities discouraged commercial development.

UNITED STATES

In the following summarized statement, reference is made to certain companies and individuals who have been interested at various times, in the development of processes for recovery of hydrocarbons from bituminous sand. This statement furnishes an interesting comment on the interest that has been aroused in the problem, and renders available, for convenient reference in condensed form, a large mass of data, gathered from scattered sources. Although certain of the processes referred to have proved impracticable, nevertheless an outline of methods employed should prevent duplication of effort, and possibly subsequent patent infringements. The writer has observed, particularly in Oklahoma, that similar impracticable devices have been repeatedly introduced in a succession of plants.

All plants constructed in the United States prior to 1913, have long since been dismantled or destroyed by fire, and only occasional rusted boilers and tanks now remain. Apart from plants operated by the Tar Springs Refining Company and the Uvalde Rock Asphalt Company, authentic records regarding operations are practically non-existent. The

[1] Concerning Bitumens (Goudrons) Produced in Russia. A report by H. K. Lipinski of the First (Chemical) Division, Imperial Russian Technical Society; Dec. 20, 1895.

evidence, however, appears to be sufficiently complete to indicate that separation methods, as developed prior to 1913, would not be applicable to the treatment of Alberta bituminous sand on a large commercial scale, and under present labour and market conditions.

Failure to develop a commercially successful separation process prior to 1913, was due to the use of inapplicable principles and unperfected mechanical devices. To a lesser extent, legitimate competition with other and cheaper bituminous products, trade competition not based on normal conditions, and shortage of funds, particularly during critical periods of experimental operation, have also militated against success. In certain instances, limited throughput capacity, resulting in unduly high overhead charges; local conditions, including high transportation and mining costs; selection of bituminous rock not adapted to separation methods; fires and explosions, due to the inflammable nature of solvents used, have proved to be deciding factors. At times, the precise cause, or causes, for discontinuing operations are somewhat obscure, and difficult of correct interpretation.

It is not an easy matter to express an opinion regarding the relative merits of various separation plants that were operated in the United States during the period 1891-1913. As previously noted, installations have long since been dismantled, and data regarding them are meagre and incomplete. It appears, however, that of the various plants designed for the separation of bitumen from bituminous sand during the above period, the one operated by the Alcatraz Asphalt Company near Carpinteria, Cal., gave the best results.

Carpinteria bituminous sand[1] is of special interest, because of all deposits in Europe and in the United States, with which the writer is familiar, the material from it most closely resembles that of the Alberta deposit. In each instance the same features militate against its extensive use in a crude condition, namely, variation in percentage of associated bitumen and in grading of mineral aggregate, and the necessity of paying freight charges on approximately 85 per cent of associated sand.

Alcatraz Asphalt Company, Carpinteria, California. U.S. Patents 580592, 505416, (about 1891-9). (Figure 11).

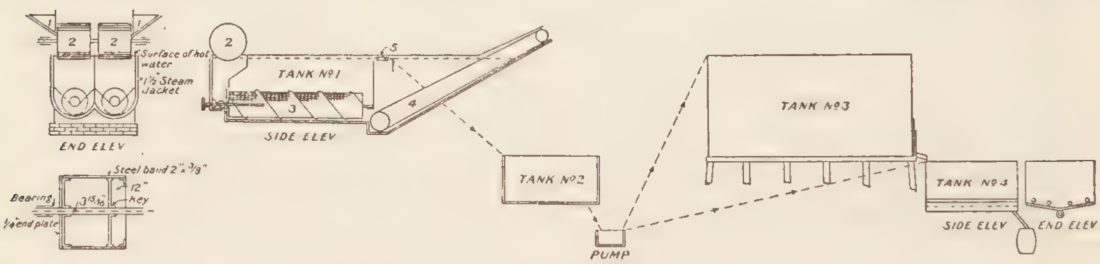


Fig. 11.—Diagrammatic outline of hot water separation plant, Alcatraz Asphalt Co., Carpinteria, Cal.

Operations by this company were on a larger scale, and were continued for a longer time than at any other plant in the United States treating similar material. About 1899, operations were discontinued. This action

[1] For reference to deposits of bituminous sand in California, see 12th Annual Report, California State Mining Bureau; 1894.

was not necessarily due to mechanical inefficiency in the process which the company had developed, for in 1893-4, the product was shipped to New York and other eastern centres, but was primarily due to the influence of certain powerful interests, to increased production of low-priced asphalts manufactured from domestic and Mexican crude petroleum, and to the exhaustion of certain of the supplies of raw materials necessary for the operation of the Carpinteria plant.

Operations at Carpinteria were commenced about 1891, and were continued until the autumn of 1899. Eventually, the capacity of the plant reached approximately 100 tons of crude rock per 24 hours—equivalent to about 15 tons of refined bitumen. The soft bitumen recovered was used largely in fluxing the hard asphalt mined by the Alcatraz Company at La Patera, Ventura county, California. Water heated to approximately 212° F. at atmospheric pressure, was the sole medium for separating the bitumen from the associated sand. Mining conditions were favourable, and mining costs low. The area of bituminous sand was approximately 70 acres in extent and the thickness of the bed from 20 to 25 feet. The separation plant was adjacent to the quarry and close to the sea-shore. The overburden consisted of 8 to 10 feet of sandy loam, and was hydraulicked directly into the ocean. The bituminous sand was excavated by means of heated spades, and loaded by hand into push cars of about 2 tons capacity. The cars were trammed to the foot of an incline, and hauled by cable to the charging-floor. Here the sand was fed by hand into the hoppers (1), (Figure 11), the bottoms of which were steam-jacketed. From the hoppers, the sand passed into a pair of bar disintegrators (2) equipped with half-inch bars of tool steel, and with half-inch openings and set above separation tank No. 1. These disintegrators had a speed of about 30 r.p.m., and were so set that the revolving bars passed 8 inches below the surface of the water. Impact against the bars, together with the action of the heated water, gave a rapid and satisfactory disintegration. From the disintegrators, the sand fell into the hot water in tank No. 1. The tank contained two compartments. In the first a part separation of the bitumen took place, the partly leached material being carried into the second compartment by a slowly moving screw-conveyer, 12 inches in diameter. An adjustable wearing-plate was arranged below the conveyer. The conveyer discharged the bituminous sand into a specially designed trommel (3), where further separation of the bitumen was effected. The trommel was constructed of thin steel ($\frac{1}{16}$-inch), with stamped perforations $\frac{1}{8}$ by $\frac{5}{16}$-inch. The shaft was 4 inches square and to it a screw conveyer was attached by webs set at intervals of 12 inches, held apart by suitable spacers. The outer surface of the trommel was also equipped with a screw-conveyer, turning above a wearing-plate. By this means, the waste sand which passed through the slotted openings, as well as that which remained in the trommel, was moved along to a boot, whence it was carried by elevator (4) to a point of discharge. The waste sand from No. 1 tank was probably 98 per cent clean. The bitumen rose to the surface, and was drawn off at (5). The product from this tank is said to have been 70 to 75 per cent pure, the impurities consisting of water, sand and silt.

From tank No. 1, the partly refined product passed to tank No. 2—a steam-jacketed tank provided with steam coils, and having a semicircular bottom. At the Carpinteria plant, this tank was 50 feet long, 3½ feet deep and 3 feet wide. Although intended primarily for storage, a certain amount of water and sand also separated out here. In Figure 11 this tank is shown as being comparatively small, as it seems unnecessary to introduce so large a receptacle at this point.

From tank No. 2, the bitumen usually passed to refining tanks No. 4. If, however, these were overcrowded, the bitumen passed to a steam-jacketed pump (4-inch plunger, 14-inch stroke, vulcanite valves), which elevated it to the main storage tank No. 3. This tank was situated 18 feet above No. 2, had a large capacity, and was constructed of ¼-inch steel. Instead of being jacketed, it had a set of steam coils laid in the bottom, and another bank of coils near the outlet. Discharge was by means of a gate-valve, 12 by 18 inches. The relative specific gravities of the cooling bitumen and water did not permit a definite and complete separation of the two, and it was found that lenses or pockets of water formed at various elevations throughout the mass. Consequently a series of offtake cocks was provided, by means of which water could be drawn off from any elevation at which it might collect.

From tank No. 3 (or tank No. 2 as the case might be), the bitumen flowed by gravity to the refining tank No. 4. Here the last traces of moisture were removed, and a portion of the remaining silt settled out. The bottoms of these tanks were steam-jacketed (1½-inch), and in addition, four 1½-inch perforated pipes were laid longitudinally along the bottom. Hot air at a pressure of 12 to 15 pounds, was introduced through these pipes and assisted in the removal of steam bubbles. By using superheated steam in the jackets and coils, the temperature of the bitumen was raised to 300° F., care being required to prevent excessive frothing. After frothing ceased, the temperature was increased to 315° F. to 320° F., and the refining was then complete. Such sand or silt as settled out, was removed at intervals by shovels. In order that the bitumen might cool somewhat before reaching the barrels, an intermediate storage tank was introduced. Throughout the plant, insulating by means of asbestos board was resorted to extensively, in order to reduce heat losses.

In its operation, the plant appears to have been fairly successful, and it is stated by A. F. L. Bell, the company's general manager, that at the time operations ceased, asphalt was being produced at a cost of approximately $12 per ton. It is evident that changes could have been introduced with advantage. The method of using steam might be modified, and the relative position of tanks arranged so as to reduce piping and pumping to a minimum. The shape of the tank bottoms (especially that of No. 3) could be advantageously modified, and mechanical devices introduced for facilitating removal of silt and sand. Wooden pent houses were erected over all tanks. Possibly fumes passing off during refining could be recovered and condensed.

In operating the above plant, it is said that steam was generated by two 75 h.p. boilers. At one time bituminous sand was used as fuel.

No special grates or mechanical stokers were used and labour costs were high. When the cost of coal fell to $17 per ton the use of bituminous sand as fuel was discontinued.

Alcatraz Asphalt Company[1], *Sisquoc, California. U.S. Patents 581451, 596468, 617712, 655430, (about 1899-1901).*

As an instance of the commercial separation of bitumen from bituminous sand, by the use of a petroleum distillate, the celebrated Sisquoc plant[2] may be mentioned. Subsequent to the closing down of operations at Carpinteria—and at the subsidiary mine of La Patera, where an almost pure, hard bitumen was mined from fissure veins—the Alcatraz Company, erected a large solvent separation plant near Sisquoc, 25 miles southeast of Santa Maria, in Santa Barbara county. A tram line, operated by gravity, conveyed the bituminous sand a distance of approximately 1,000 feet, to the separation plant, where it was discharged into a large hopper. Thence it was passed through a series of steel crushing rolls, and fed into large, revolving, steel-jacketed heating-drums. As it became softened, the bituminous sand was met by an inflow of solvent, (petroleum distillate of approximately 50° Bé.), and when thoroughly disintegrated, passed into other revolving-drums which served as agitators.

The above plant was situated approximately 26 miles to the east of Port Gaviota, with which point it was connected by means of a double pipe line. From the agitators, the solvent, together with a considerable percentage of separated bitumen, was piped under a gravity head to the refinery at the coast. There the solvent was distilled, and pumped back to the separation plant for further use. The bitumen itself was withdrawn to cooling-chambers and thence tapped into barrels. It appears that this product was of good quality, due in part, to the low temperatures adopted throughout. Recovery of solvent from spent sand, entailed considerable expense. It is said that mining costs did not exceed 25 cents per ton; that the loss of solvent varied from 3 to 5 per cent; and that the total cost of bitumen did not exceed $14.00 per ton.

It is stated on reliable authority, that the cost of the above installation represented an expenditure of approximately $1,000,000. About 1901, control of the Alcatraz Company was secured by the Asphalt Company of America, and the Sisquoc plant closed down. Equipment has long since been dismantled, and the greater part removed.

Alberta Tar Sands Products Company, Ltd., Edmonton, Alberta; Canadian Patents 237508 and 238772, (1924)

As a result of an extensive investigation undertaken by Mr. Emory E. Smith, 651 Howard St., San Francisco, Cal., it is proposed to recover as liquid hydrocarbons, a part of the bitumen associated with bituminous sand. The residue would be used as a paving material—notably in the manufacture of paving blocks adapted to the construction of various types of wearing surfaces.

[1] It is stated (See Mineral Industry, Vol. 8) that the output of the Alcatraz Company's plants and mine amounted to 50,000 tons of bitumen in 1899.
[2] Designed by A. F. L. Bell, Chief Engr., Associated Oil Co., San Francisco, Cal.

Figure 12, which should be regarded as purely diagrammatic, illustrates the general procedure suggested. Bituminous sand is introduced by a conveyer (1) into a preheating chamber (2). A suitable type of conveyer (3) delivers the material to a bin (4), from which it is conveyed through an intermediate heater (5) to bin (7), and into still (8). This is externally heated by furnace gases (9), and if desired, by superheated steam delivered at point (10). In the still, agitating arms (11), serve to complete disintegration and liberate petroleum vapours, which then pass off through ducts (12), and may be used to preheat material in chambers (2) and (5). If desired, these vapours may be condensed and recovered as a by-product.

From the still (8), the partly distilled material passes to a cooling-chamber (13), where crushed stone or other desired mineral aggregate may

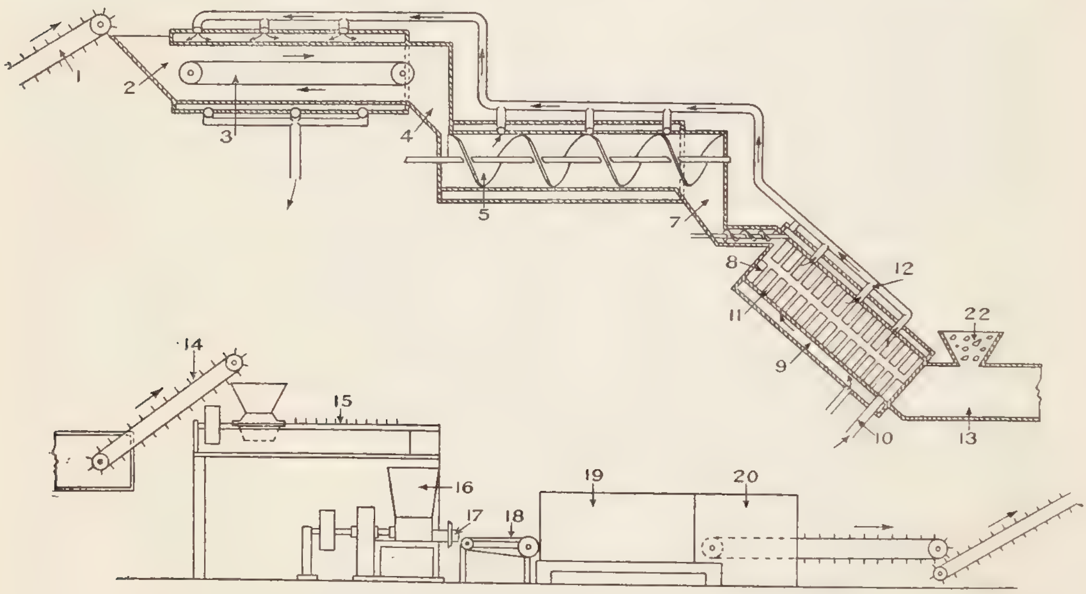


Fig. 12.—Diagrammatic outline of process patented by Alberta Tar Sands Products Co., Ltd.

be added through hopper (22). The mixture is then conveyed by elevator (14) to pug mill (15), and is then forced by a press (16), through an outlet orifice (17) and cut into required shapes by suitable mechanical appliances. Instead, if desired, the mixture from the pug mill may be carried on the measuring belt (18) to the cutting-machine (19), and subsequently given a coating of lime dust or other suitable material in chamber (20). From this chamber the finished blocks may be delivered to storage by carrier.

So far as the writer is aware, this process has not been demonstrated on a scale sufficiently large to indicate its commercial possibilities.

American Mineral Wax Company, Woodford, Okla., (about 1909). (Figure 13).

Following the destruction by fire of his separation plant near Ardmore, Okla., Mr. A. Snyder undertook the development of a second process near Woodford under the name of the American Mineral Wax Company.

Analysis of bituminous sandstone mined at Woodford indicated an average content of bitumen ranging from 8 to 10 per cent, with a maximum of 12 per cent. The bituminized stratum is from 20 to 30 feet in thickness, and dips at an angle 85 to 90 degrees (Plate XLI, page 184). In hand-sorting the broken rock, it was considered by quarrymen that any pieces which readily soiled the hands still retained a sufficient percentage of the lighter oils to cause the bitumen to rise to the surface of the water. It was usually found that rock which did not soil the hands was not adapted to a hot water separation process.

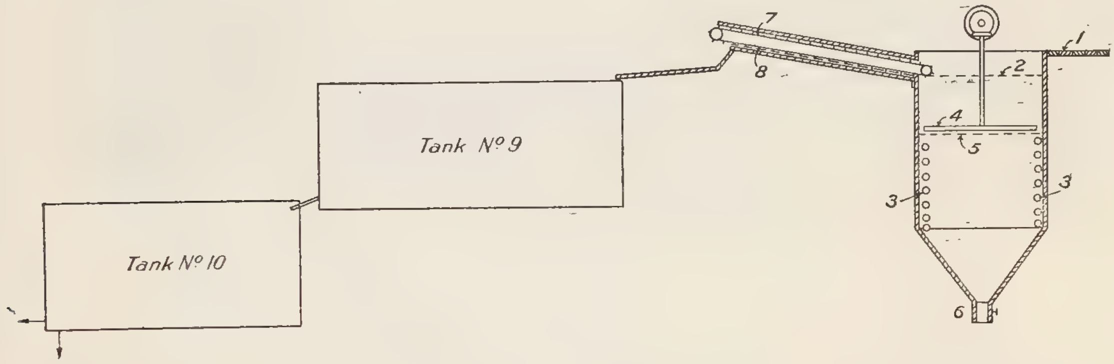


Fig. 13.—Outline of separation process developed by American Mineral Wax Company, Woodford, Okla.

Bituminous sandstone, broken to pass a 12-inch ring, was fed from charging-platform (1), into a circular, metal disintegrating-tank, $3\frac{1}{2}$ feet in diameter and 8 feet deep. This tank was partly filled with water to level (2), and heated by means of steam coils (3). A series of heavy metal disintegrating arms (4), were rotated at a depth of 18 inches below the surface of the water, above a heavy metal plate (5), punched with $\frac{1}{8}$-inch openings. The disintegrated sandstone passed through this perforated plate, and was discharged through a 6-inch core valve (6). The partly purified bitumen rose to the surface of the water, and was removed by a sprocket-driven belt-skimmer (7), over a perforated screen (8), which permitted a part of the water to flow back into the separation tank. A 12-inch lump of freshly mined rock required approximately 15 minutes for disintegration, but exposure to the atmosphere for 12 hours, is said to have caused an appreciable difference in the rate at which separation took place. Lumps of pyrite and impure partings were not uncommon, and retarded disintegration.

The product, consisting of bitumen, sand and water, was discharged into settling-tank (9). Here after cooling, sand and bitumen settled to the bottom, and the water was tapped off at a higher level. When it was desired to draw off the bitumen, which contained about 20 per cent of sand and a small percentage of water, into the "cooker" tank (10), steam was turned into a bank of coils about outlet. Tank (10) was steam-jacketed and equipped with banks of steam coils on sides and bottom. Here the water was driven off, the sand settled to the bottom, and the bitumen tapped into barrels.

The plant described above was destroyed by fire prior to 1913. The nominal capacity was 2½ tons refined asphalt per 10 hours. From information supplied by a former superintendent, Mr. E. F. Riser, it appears that mining and separation costs amounted to almost $16 per ton (2,000 pounds) refined asphalt. The staff, comprising one shift, together with wages paid, is summarized as follows: 1 foreman at $1.50, 1 engineer at $2, 1 disintegrator man $1.50, 1 valve man at $1.50, 1 man at "cookers" at $1.50, 3 quarrymen at $1.50, 2 labourers at $1.25.

Ash, H. W., Cambridge, Mass. U.S. Patents 757387; 779198; Serial Nos. 103347; 162562, (1905). (Figure 14).

The principal features of this process, include a vertical cylindrical metal retort (1) above a furnace (2) together with blower (3) and a condenser (4). A number of horizontal, perforated metal trays (5) are provided in the retorting-chamber, and on these the charge rests. Heated

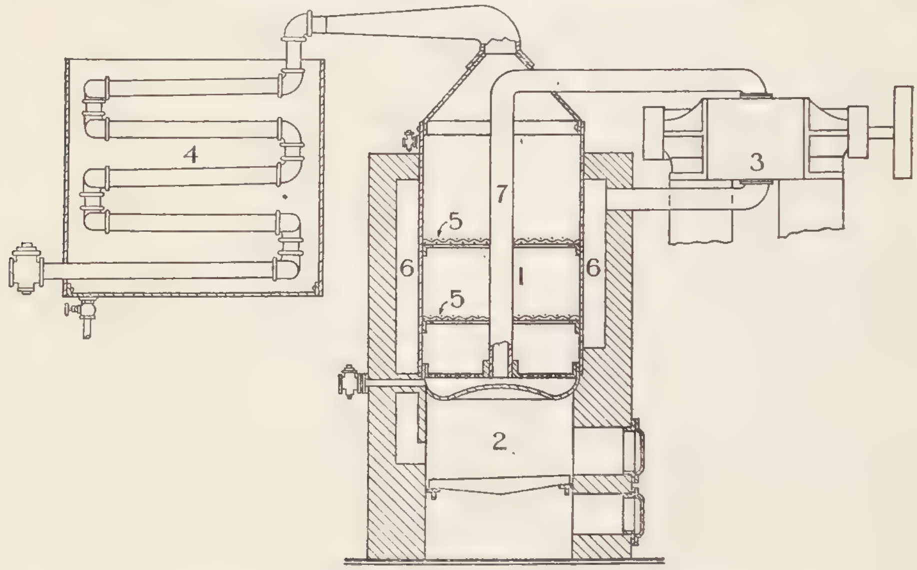


Fig. 14.—Apparatus for distillation of bituminous materials, H. W. Ash.

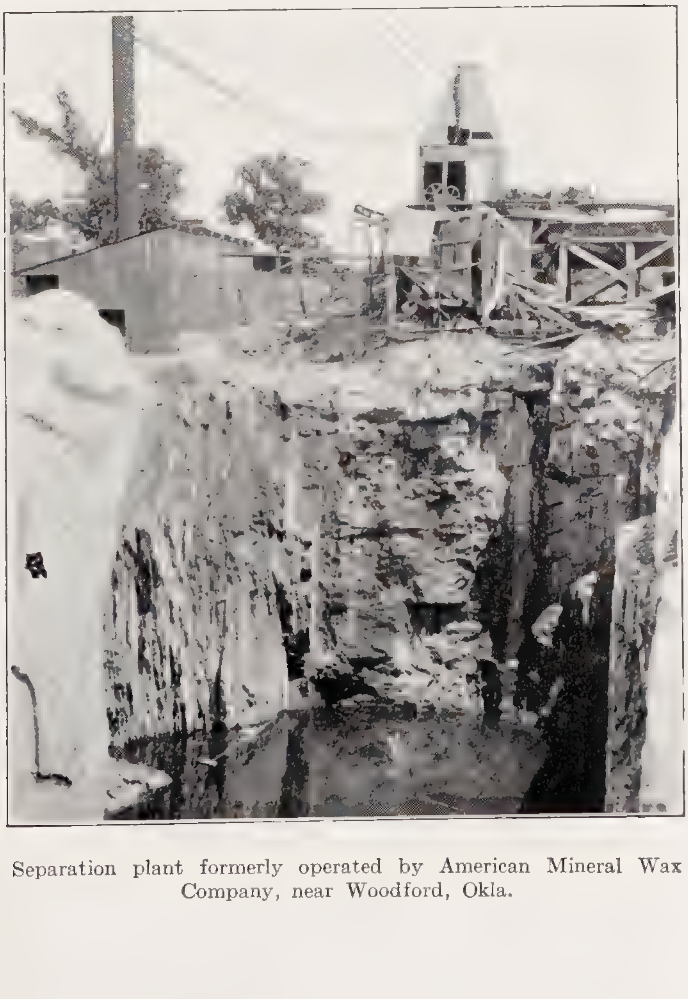
gases from the furnace pass through an annular space (6) provided in the brickwork about the retort, and thence to the blower or fan (3). The gases then descend through a vertical flue (7) in the centre of the retort, and are forced upwards through a perforated metal plate to the bituminous material undergoing distillation.

Information indicates that demonstration of the above process was not carried beyond small-scale experimental work.

Athabaska Petroleum Products, Ltd., 502 Union Trust Bldg., Winnipeg, Man., (1923-4). (Owners of N. S. Clark patents and processes, including Canadian Patents 241237, 241238 and 241240) (1923). (Figure 15.)

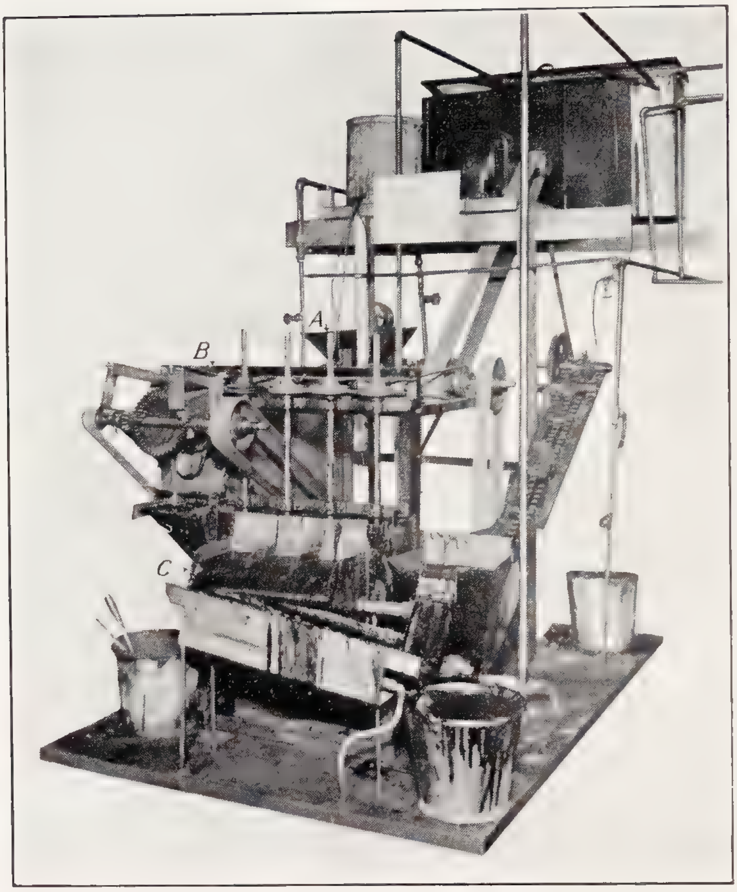
The bituminous sand is introduced through a hopper into a relatively high, (30 to 40 feet) jacketed, metal stack or chamber (1), in which part disintegration is effected in the presence of superheated steam, introduced

Battery of jack-hammer drills at quarry, near Cline, Texas, Uvalde Rock Asphalt Company.



Separation plant formerly operated by American Mineral Wax Company, near Woodford, Okla.

Plate XLII



Experimental separation plant designed by J. M. McClave, Bituminous Sands Company. A, feed hopper; B, pug mill; C, flotation cells.

Plate XLIII

Demonstration of Georgeson process on Horse river, Alberta, January, 1924.

at points (2), and hydrocarbon gas. Pressure may vary from 50 to 100 pounds. The section of the lower part of the stack is reduced, in order to retard downward movement of material, and is also equipped with steam inlets (2). The partly disintegrated bituminous sand then passes, by gravity, through a gate-controlled opening, to a series of chambers (3) partly filled with heated water and equipped with rotary spray nozzles (4). Other nozzles may be provided to facilitate movement of material. Spent sand is removed from the last chamber of the series, by any standard device (5). Water level is adjusted as desired.

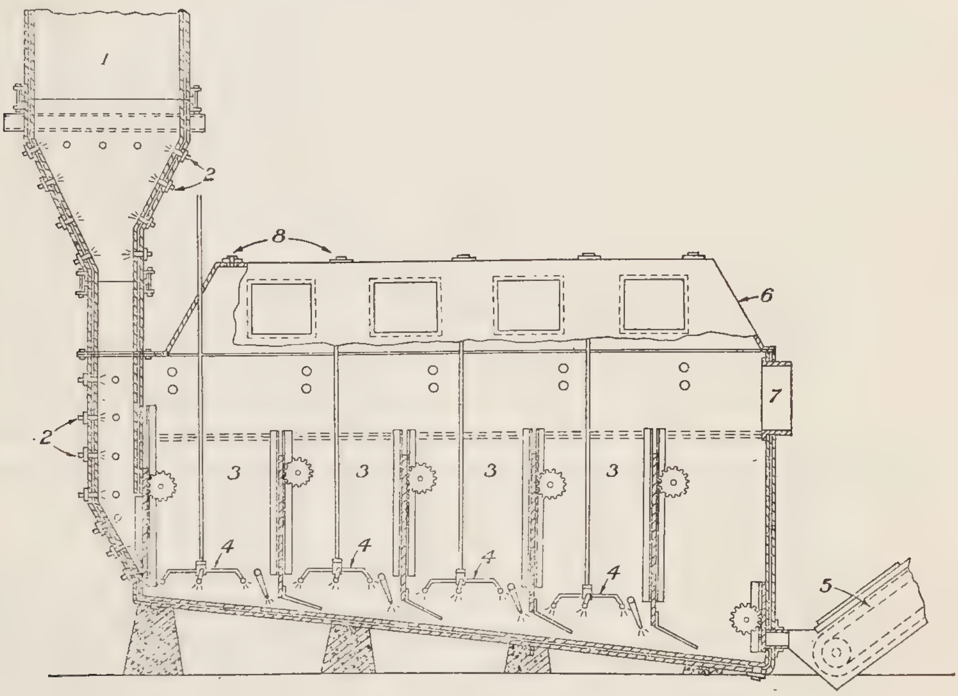


Fig. 15.—Apparatus for treatment of bituminous sand, Athabaska Petroleum Products, Ltd.

As the semi-fluid bituminous sand pulp passes through the chambers (3), enclosed within the main housing (6), separated bitumen and oil rise to the surface of the water, and are withdrawn near water level at offtake (7). Gaseous products are withdrawn at offtakes (8).

It is claimed that the apparatus, as designed, is automatic in operation, of simple construction, and may be adjusted in accordance with the character of the bituminous sand treated.

Bergius Process; Dr. Frederick Bergius, Germany.

The process consists of the treatment, with hydrogen under high pressure, of such materials as asphaltic residues, pitch, coal tar and coal, and it is claimed to be adaptable to the recovery of bitumen from Alberta bituminous sands. The pressure used is 1,000 to 1,500 pounds, that is approximately up to 100 atmospheres, and the optimum temperature in the neighbourhood of 750° F. (400° C.). By this method it is claimed that a 15 per cent yield of light (naphtha and illuminating) oil, as obtained by

ordinary destructive distillation of the bituminous sand can, by the Bergius process, be increased to as high as 60 per cent with a corresponding decrease in the heavy (lubricating) oils and pitch residue. Although this process has apparently passed through the laboratory and semi-commercial stages it has not as yet become commercially successful.

Bituminous Sands Company, 1104 First National Bank Building, Denver, Colo. (Formerly known as the American-Canadian Oil Products Company.) Canadian Patent 234272, (1923).

Early in 1923, Mr. J. M. McClave, Director, Western Research Laboratories, Denver, Colo., conducted a series of experiments in Denver, in order to demonstrate the efficiency of water flotation when applied to treatment of bituminous sand. A novel feature of the McClave process consists in introducing into the water a small percentage of bentonite.[1] In some cases (depending on the character of bentonite used) a small amount of sodium silicate, or other alkaline reagent, is also added.

In conducting experiments, on a laboratory scale, water in which 1½ to 2½ per cent of bentonite had been disintegrated, was used as a solvent. The bentonite-sodium silicate aqueous mixture, at a temperature of approximately 120° F., rapidly disintegrated all fragments of bituminous sand, and the resulting pulp was fed into a small pug mill heated to 200° F. In this mill, part separation was effected, but the greater part of the pulp was further treated in a small two-compartment flotation cell. From this cell, clean spent sand was removed by an elevator, and a mastic product, containing a large percentage of water and air, approximately 20 per cent fine mineral aggregate, and bitumen, was recovered.

During the summer of 1923, a sum of $12,500 was expended in construction and operation of a semi-commercial plant with a capacity of 25 tons per 24 hours, near San Luis Obispo, Cal. Its essential features comprised a pug mill, flotation cells, settling-tank and topping still. The plant was operated for a period of 30 days.

By the McClave process as recently modified, preliminary separation is effected in the pug mill and flotation cells, and the product then passes to a special centrifugal machine which removes the air and water. The product is then passed to storage tanks for final treatment in a continuous retort, where any combined water is first removed and the lighter oils then recovered by distillation. The asphalt product is discharged continuously without distillation. This completes the treatment, giving a crude oil similar to well oil that is ready for the refinery, and a marketable asphalt product that has not been subjected to high temperatures.

In 1924 the Bituminous Sands Company was organized by Mr. Robert M. Birck of Chicago, and a second laboratory unit (Plate XLII), having a capacity of 1 ton of bituminous sand per 24 hours, was constructed in Denver. As a result of the experimental work conducted during 1924, certain minor modifications have been introduced resulting in increased efficiency. Estimates of construction and operating costs have also been

[1] In October, 1924, the writer secured a sample of bentonite from a deposit situated on the S.E. ¼, sec. 30, tp. 57, range 1, W. of the 5th meridian. The material resembles the bentonite from the Camrose and Red Deer valley occurrences.

prepared by Mr. McClave in collaboration with Mr. Merrill Hibbard, Chief Engineer, Jeffrey Manufacturing Co., Columbus, Ohio. These are based on a throughput of 1,000 tons bituminous sand per 24 hours, for 200 working days per year, (with common labour at $4 per day and coal at $7.50 per ton) and may be briefly summarized as follows: —

Estimated mining cost, separation cost, and cost of retorting product from separation treatment. Based on one ton of bituminous sand, and including supervision, depreciation at 20 per cent and interest at 6 per cent.

Stripping cost per ton of bituminous sand....	$0.10	(assumed thickness of overburden, 20 feet).
Mining cost per ton of bituminous sand at 10c.	0.20	(doubled to allow for unfavourable conditions).
Cost of treating bituminous sand per ton......	0.45	
Removal of waste sand tailings................	0.10	
	$0.85	maximum cost.

With a longer operating season the above cost would be somewhat reduced.

Brownley, Edwin H., Calvert Building, Baltimore, Md., (1924).

No definite information regarding this process is available

California Oil Mining Corporation, Baltimore, Md. (1923).

In 1923 the above corporation undertook the erection of a commercial unit near San Luis Obispo, Cal., designed for the recovery of hydrocarbons from bituminous sand. The capacity of the plant is estimated at 500 tons per 24 hours.

Crude bituminous sand is fed into a disintegrator equipped with two heavy screw-conveyers, 18 inches in diameter, and partly filled with hot water and a small percentage of petroleum distillate. Pulp from the disintegrator passes to a Cottrell vibrating screen to remove pebbles and oversize lumps, and is then discharged into a second mixer where further distillate is added and complete disintegration is effected. The pulp is then passed through K. and K. flotation cells, where 60 per cent of the sand content is dropped. The concentrate containing about 40 per cent sand, is passed to a heating-tank, then to an agitation tank, then to a specially designed horizontal retort, and finally to a Southwestern Engineering Company condenser, where desired cuts are made.

It is said that the plant referred to above represents an investment of upwards of $75,000. In November, 1923, construction was nearing completion but actual operation has not commenced.

Canada Supercoal Ltd., 507 Montreal Trust Bldg., Montreal.

This company controls patents issued and applied for by Dr. F. T. Snyder. The process aims at recovery of hydrocarbons from bituminous sand, by means of low partial pressure distillation at temperatures below the boiling-point of hydrocarbons recovered. Pending the granting of certain patents, the company do not wish to announce any details of methods employed.

Clark, K. A., University of Alberta, Edmonton, (1922-24)[1]

Following a comprehensive preliminary investigation on a laboratory scale, a semi-commercial plant was installed at the University of Alberta in the spring of 1923. It is stated that approximately 85 tons of bituminous sand was successfully treated by this plant[2].

Bituminous sand is first treated with heated water containing a small percentage of silicate of soda. The pulp then passes through a series of mixing boxes and separation boxes, the latter providing quiet water zones where separation of sand and bitumen is effected. Partly refined bitumen overflows and is collected, and the waste sand is removed by a simple mechanical device.

In 1924 a somewhat larger demonstration plant was erected and operated near the Alberta and Great Waterways Railway station, on the St. Albert trail. A complete statement dealing with the above investigation is being prepared by Dr. K. A. Clark.

Claytor, Edwin E.; Canadian patents pending and assigned to Chas. P. Mackie, 80 Maiden Lane, New York, (1925).

Recovery of bitumen from bituminous sand depends primarily on the action of a weak, heated, aqueous alkaline solution. Preliminary separation may be effected either in situ by introducing the solution through cased wells drilled to the bituminous sand stratum, or by directing the solution by hydraulic guns or otherwise against the walls of the wells or a quarry-face.

When the solution is introduced through wells, it is anticipated by the owners of the Claytor process, "that the major portion of the sand and solution will remain in the chambered cavity, and that the liquid hydrocarbon will be recovered as a relatively clean product. It is further anticipated that in the case of deep wells, the alkaline solution may be cycled within the well and cavity." In quarries or shallow wells, the product, consisting of a mixture of solution, sand, and liquid or semi-liquid sand, and liquid or semi-liquid hydrocarbons, is subsequently passed to a separator of the spitzkasten type where the sand is removed. Recovery of heat from solution used is provided for, and estimated costs are low.

It is claimed that the above process is also adapted to more complete recovery of petroleum in oil-fields where production by recognized standard drilling and pumping methods is no longer possible.[3]

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[1] The Press Bulletin, Department of Extension, University of Alberta, No. 11, Vol. IX., May, 1924. Third Annual Report of the Scientific and Industrial Research Council of Alberta, 1922.

[2] Bituminous sand was shipped from the quarry operated at Waterways, Alta., by the McMurray Asphaltum & Oil Co., Ltd.

[3] Lewis, J. O.; Methods for Increasing the Recovery from Oil Sands; Bull. 148, U.S. Bureau of Mines, 1917, p. 26. Beal, Carl H. and Lewis, J. O.; Some Principles Governing the Production of Oil Wells; Bull. 194, U.S. Bureau of Mines, 1921, p. 7; Beal, Carl H.; The Decline and Ultimate Production of Oil Properties; Bull. 177, U.S. Bureau of Mines, 1919, p. 141.

Continental Asphalt Company, Ardmore, Okla., (1910).

About 1910 the above company erected a small separation plant about 4 miles from Ardmore, at a reported cost of approximately $25,000. Separation was effected by means of heated water, the bituminous sand being passed through a series of tanks providing agitation and quiet water zones. It appears that results were discouraging and work was abandoned after a number of months. Subsequently the plant was dismantled and removed, and in 1913 practically no evidences of it remained.

Conyngton Asphalt Company, Woodford, Okla.

The company erected a small hot water separation plant near Woodford, Okla., about 1909 (?). It is said that the nominal capacity was approximately 2 tons refined bitumen per 24 hours, but no details are available regarding methods employed. Operations were discontinued and the plant dismantled prior to 1912.

Coogan, Jesse, Jesse Coogan Engineering Company, Salt Lake City, Utah, Canadian Patent 207590, (1920).

The Coogan process for recovery of hydrocarbons associated with bituminous sands embodies two stages of treatment. During the first stage, petroleum distillate is mixed with the crude bituminous sand. This softens the material, and to some extent breaks down the bond between mineral aggregate and associated bitumen.

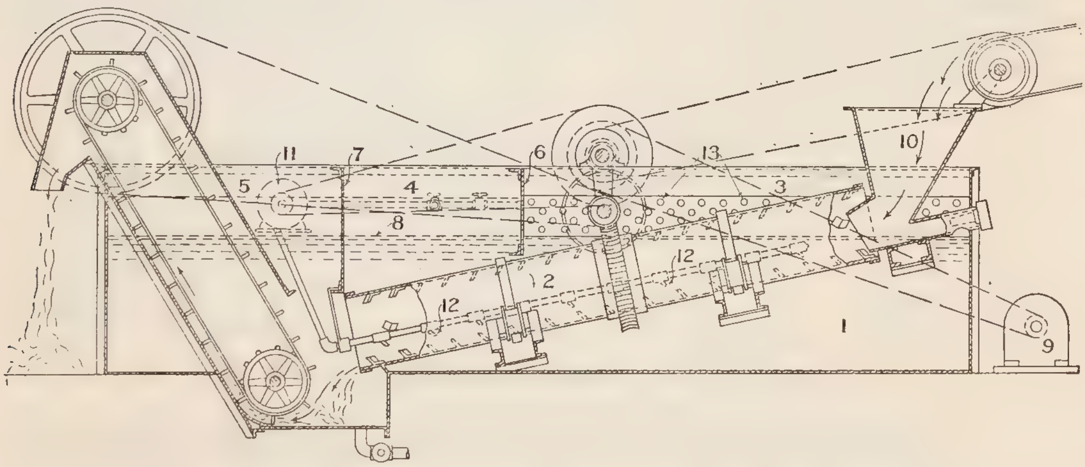

Fig. 16.—Apparatus for treatment of bituminous sand, Jesse Coogan.

In the second stage the partly digested product passes to a receptacle partly filled with heated water, and is propelled through a specially designed, inclined perforated cylinder. Devices are provided for discharging spent sand, and for removing liberated bitumen and oil from the surface of the water.

Figure 16 illustrates a longitudinal section of apparatus as designed. This consists essentially of a tank (1) and rotary agitator (2) which may be mounted either in a horizontal or in an inclined position. The tank is subdivided into compartments (3), (4) and (5), by relatively shallow partition (6) and somewhat deeper partition (7).

In operation, the tank is partly filled with water, to level (8), and a quantity of gasoline or other suitable liquid hydrocarbon introduced into compartment (3). Motor (9) is then started, and the bituminous sand introduced through hopper (10), passes through the layer of gasoline or oil in compartment (3) and thence into rotary agitator (2). Here agitation and disintegration is effected by lifting-plates and baffles. This action is accelerated by introduction of petroleum, forced by centrifugal pump (11) through a series of multiple inclined nozzles (12) which also tends to establish a current toward the upper end of the rotary agitator. Separated bitumen rises to the surface of compartment (3) and passes through perforations (13) in the sides of the compartment to exterior collecting channels.

Cook, W. H., New Orleans, La. U.S. Patent 652594, (1900).

This process is designed for the treatment of fluid and of semi-fluid materials (such as aqueous mixtures of bituminous sand) in a rotating perforated metal cylinder, provided with a suitable filtering medium.

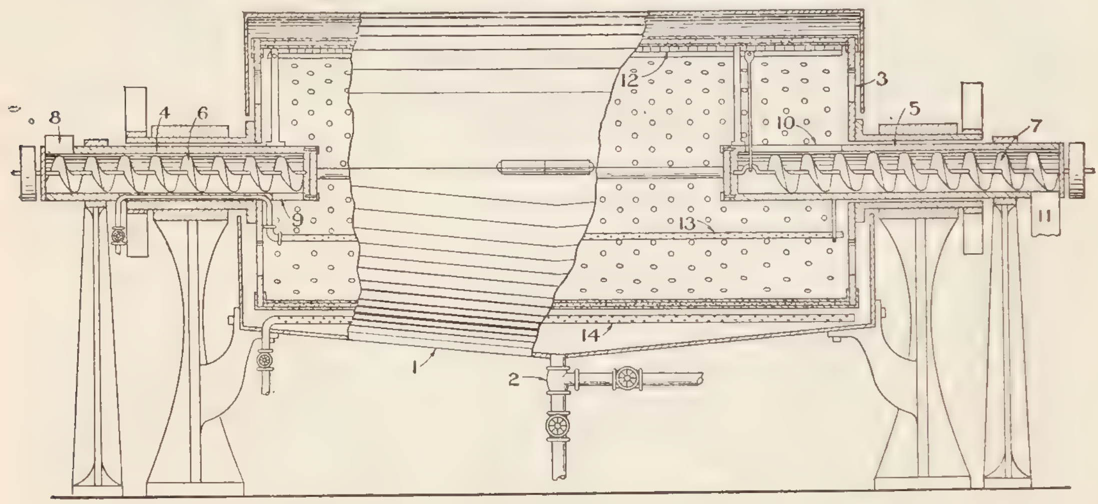

Fig. 17.—Apparatus for treatment of bituminous sand, W. H. Cook.

The general arrangement of the apparatus is illustrated in Figure 17, (1) is an outerhinged, metal housing, depressed toward the middle, and provided with discharge pipe (2). Within this housing is a belt-driven metal cylinder (3), supported by hollow trunnions provided with driving pulleys. The shell of the cylinder consists of two concentric perforated metal plates, between which is a suitable filtering medium. Stationary cylinders (4) and (5) enclose spiral conveyers (6) and (7). Cylinder (4) is provided with a feed opening (8), and a discharge opening (9). Cylinder (5) also has an opening (10) for receiving waste sand and a discharge opening (11); (12) is a specially designed scraper bar (operated by a pitman and crank), on which are arranged a series of deflection plates. Steam, compressed air, or heated water, may be introduced through perforated pipes (13) and (14).

Aqueous pulp or other material to be treated is introduced at (8) and enters the filtering-drum at (9). The filtrate is removed at (2), and the waste material, propelled by deflection plates on scraper bar, is discharged through spiral conveyer (7).

Cooper, A. S., San Francisco, Cal. U.S. Patents 507885 (1893) and 617226 (1899).

Arrangement of apparatus is indicated diagrammatically in Figure 18. Principal features include a heated disintegrator (1), a mixing-chamber (2), a separating-chamber (3), and a distillation chamber (4).

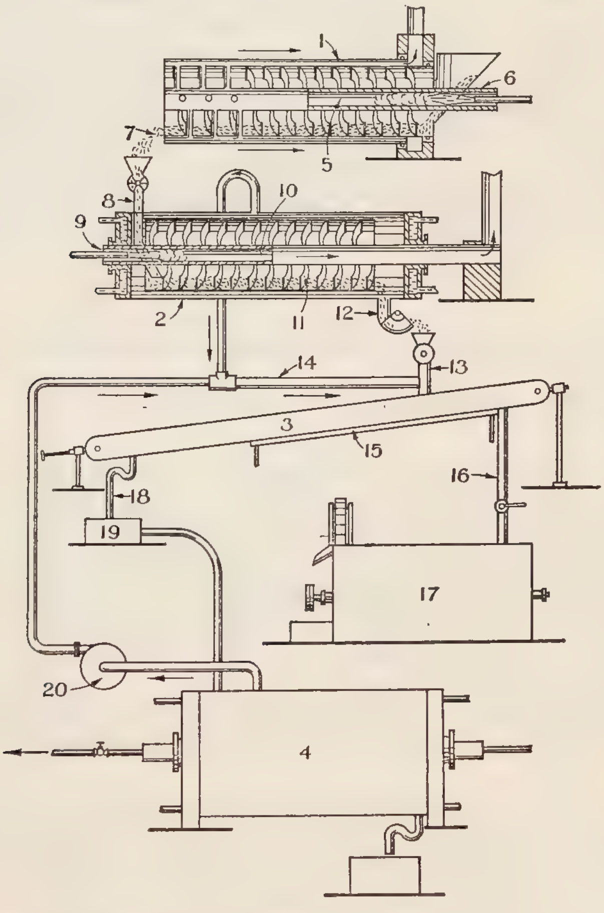

Fig. 18.—Diagrammatic outline of process for treatment of bituminous sand, A. S. Cooper.

Disintegrator (1) consists of two gear-driven, rotating, concentric, cylindrical, metal shells, equipped with feeding and discharging devices. A hollow heating-pipe (5), axially arranged, conveys hot gases from a combustion chamber (6), the gases being returned to the stack through the annular space between inner and outer shells of the disintegrator. A heavy blade conveyer, secured to the axial heating-pipe, propels the bituminous sand to a point of discharge (7).

The disintegrated and heated bituminous sand, together with a suitable amount of heavy petroleum, enters mixing-chamber (2) through a hopper and cylindrical casing (8), equipped with a feed wheel. A rotating drum (9) in the mixing-chamber is equipped with an axially arranged cylindrical heating-flue (10), through which hot combustion gases are conducted to the stack. A heavy blade conveyer (11) propels the petroleum-bituminous sand mixture to a discharge opening (12), which feeds into a hopper and feed-pipe (13). A suitable solvent—such as petroleum distillate—is introduced through pipe (14), and, combining with the bituminous sand mixture enters a gas-tight extractor (separating-chamber) on the lower face of which is a water-jacket or cooling-chamber (15). In the extractor is a sprocket-driven conveyer belt, equipped with scrapers or plows, and extending about two-thirds of the length of the extractor chamber. Partly leached sand is discharged through pipe (16) to chamber (17) for further subsequent treatment. A solution consisting of solvent, crude petroleum and bitumen is withdrawn by pipe (18) through settling-tank (19) to a mechanically-agitated steam-heated distillation chamber (4). From this chamber, bitumen is withdrawn to storage, and the vapourized solvent is removed through blower (20), and returned to mixing-chamber (2), or separating-chamber (3).

Darling, S. M., 2200 Insurance Exchange, Chicago, Ill., (1919).

The following statement has been received relative to the Darling solvent process:—

The apparatus consists of nine cylinders or tubes 18 inches in diameter by 12 feet long, arranged in blocks of 3, one above the other. The oil sand is crushed and conveyed through the tubes by means of a double screw conveyer.

The two outside blocks are used as solvent machines, the sand passing downwards and the dissolved oil passing upwards through the tubes, in counter-flow. The cylinders or retorts are steam-jacketed, the temperature in the jacket being maintained at 212° to 240°F. The dissolved oils pass off continuously through a pipe from the top retort to a reservoir. Any low-boiling oils that vapourize pass along the upper part of the overflow pipe to a condenser.

The solvent used at the start is kerosene or gas oil. After the system is in operation the sands supply their own solvent oils, a constant circulation being maintained by an oil pump.

The constant friction maintained in the oil-submerged sands as they pass downwards thoroughly softens and dissolves the oil clinging to the sand, and the sand is discharged from the bottom retorts saturated with a readily removable mixture of oils. The sand is elevated continuously to a separator above the system, from which the bulk of the oils overflow to the reservoir.

The function of the centre tier of retorts is to remove the remaining oil from the sand. This is done in either of two ways:

(1) By distillation; the retorts being heated to the desired temperature and the sand conveyed through them by a single shaft conveyer, the vapours being conveyed to a condenser.

(2) By washing with hot water; a water level being maintained about midway, the oil passing upwards and the sands downwards through the water to the discharge at the bottom.

Day, Roland B., 715-19th St. N.W., Washington, D.C. Canadian Patents 185181, 188034, 188035, 188036, 188464, 199451, 230622.

Distillation of crude bituminous sand is effected in a rotary kiln at temperatures not higher than 1,000° F., the spent sand passing to a vertical gas producer. There a small percentage of coal is introduced to permit combustion of carbon associated with the sand. Heat is recovered from the hot sand by passing a current of air through it. Auxiliary equipment includes a standard condensing plant and feed scrubbers.

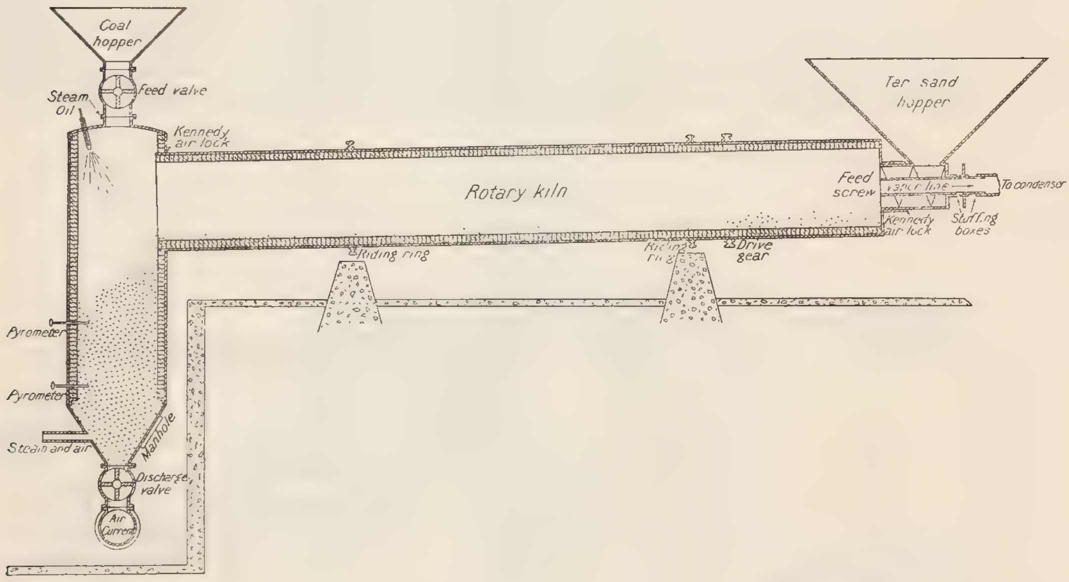

Fig. 19.—Apparatus for distillation of bituminous sand, Roland B. Day.

The general arrangement of the above system is diagrammatically illustrated in Figure 19. A retort of the type shown has an estimated capacity of 200 tons of bituminous sand per 24 hours.

Diehl, H. A., San Francisco, Cal. U.S. Patent 469777, (1892).

This process is based on the application of direct heat to a retort containing bituminous sand or similar material.

Figure 20 represents a longitudinal section of the suggested apparatus. Bituminous sand is delivered through manhole (1), on to the perforated metal diaphragm or plate of retort (2). Heat from firebox (3) causes a portion of the associated bitumen to liquefy, and this is drawn off at a suitable outlet. Volatilized hydrocarbons pass to condenser (4), and the condensate is recovered in tank (5). Water settles out and is withdrawn at (6), and the oils are removed at a higher level (7). Bitumen derived from the lower part of retort (2), is further treated by heating in retort (8), the low-boiling oils being condensed and returned to tank (5), while the residual bitumen is withdrawn from the lower portion of the retort.

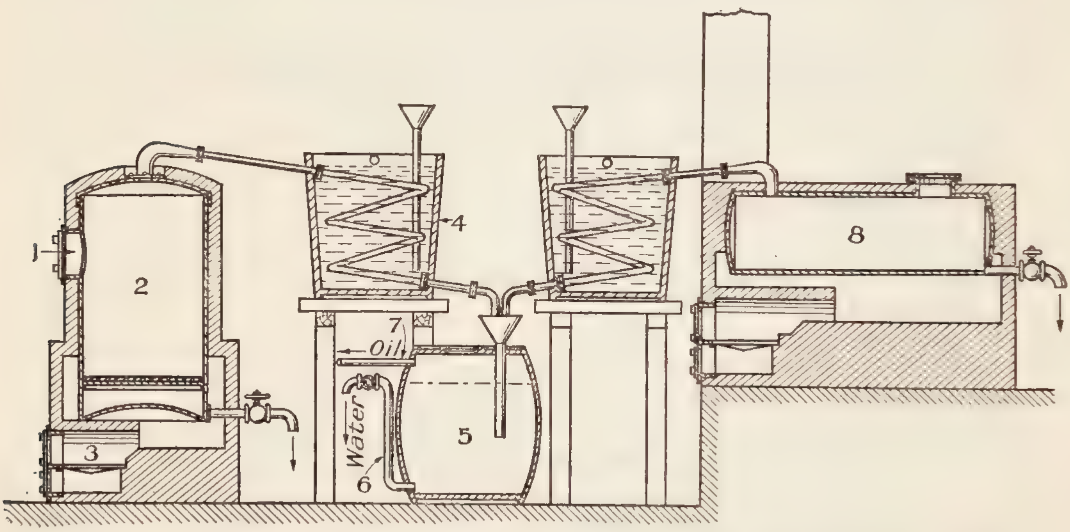

Fig. 20.—Diagrammatic outline of process for distillation of bituminous sand, H. A. Diehl.

Diver Extraction Process. (Figure 21.)

During 1920 an attempt was made near McMurray (sec. 9, tp. 89, range 9) to distil, in situ, the bitumen associated with the bituminous sand. A bore was sunk to the top of the bituminous sand stratum and cased. The bore was then continued with a somewhat decreased diameter into the bituminous sand. At the bottom of the bore a fireclay heater was provided. Gas was led from the surface, and ignited within the fireclay heater. Heat thus developed caused a limited volatilization of bitumen in the immediate vicinity, and oil vapours thus generated were led to a condenser at the surface. This effort appears to be of historical rather than of commercial interest.

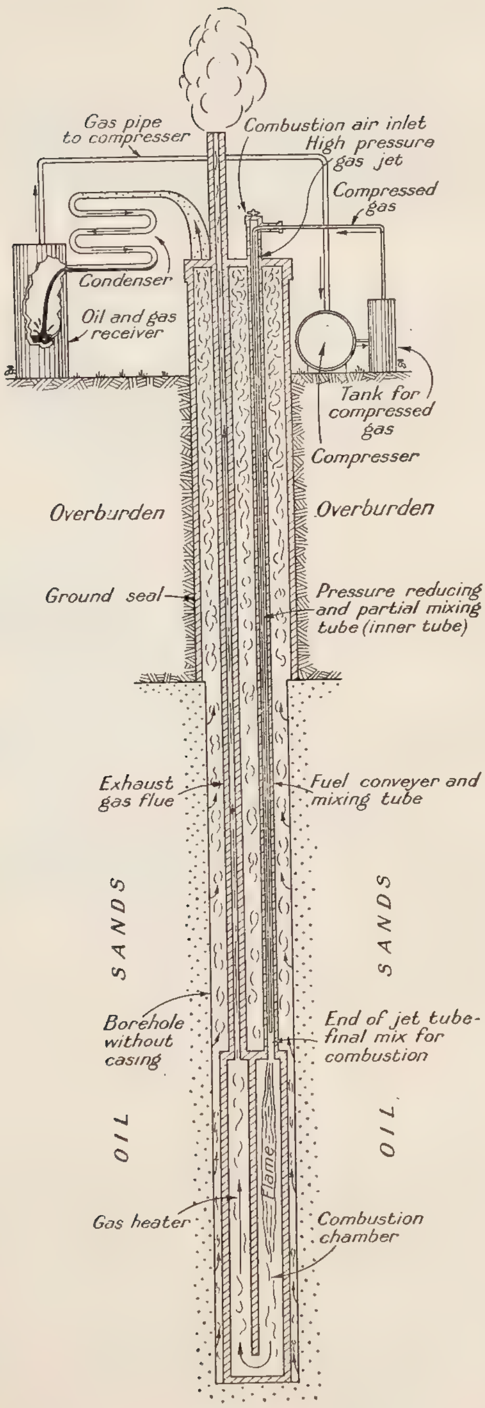

Fig. 21.—Diagrammatic illustration of method for recovering hydrocarbons from bituminous sand in situ, D. Diver.

Downard, Jas. S., Dallas, Texas. U.S. Patent 722500, (1903). (Figure 22).

During the period 1902-05, two small separation plants were designed and operated by Mr. Jas. S. Downard at a point near Ardmore, Okla. The stratum of bituminous sandstone opened up, is approximately 20 feet thick, and dips at an angle of 70 degrees. The rock itself is a medium hard sandstone carrying from 10 to 12 per cent of bitumen. In both plants separation was effected by the use of heated water and the following description outlines the general method adopted.

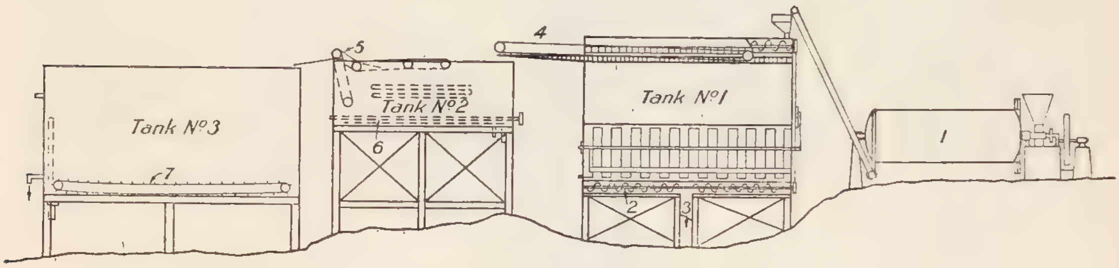

Fig. 22.—Diagrammatic outline of method for treatment of bituminous sand, Jas. S. Downard.

The bituminous sandstone was sledged and passed through a ball-mill (1), from which it was elevated to hot water tank No. 1. This tank was equipped with steam coils and heavy blade disintegrator. Waste sand was discharged by screw-conveyer (2), through valve (3), and partly purified bitumen was carried by mechanical skimmer (4), to tank No. 2. This tank was also filled with heated water and equipped with mechanical skimmer (5), steam coils, and belt scraper (6), for removing waste sand. From tank No. 2, the bitumen, together with 40 to 45 per cent sand and water passed to a settling-tank No. 3, where final separation was effected at atmospheric temperature. Water was drawn off at a series of cocks, and the bitumen at a lower level. Waste sand and sludge were removed by a belt scraper (7). It is stated that the production cost of bitumen, 80 per cent pure, was approximately $15 per ton. The capacity of the larger of the two plants was 4½ tons of refined bitumen per 10 hours.

Dutcher, C. E., 3919 California St., San Diego, Cal.

In 1921, Mr. C. E. Dutcher erected on Hangingstone river (sec. 10, tp. 89, range 9) near McMurray, a small rectangular distillation retort. The outer shell consisted of a rectangular metal box provided with a fire-box, stack, and heavy, hinged door. An inner, and somewhat smaller rectangular metal box constituted the actual distillation chamber, and was provided with an offtake for oil vapours. Charges of bituminous sand were trammed on small metal trucks into the distillation chamber, and combustion gases from the firebox, circulating through the space between inner and outer shells, developed a temperature sufficient to cause distillation of bitumen associated with the sand.

This retort is of historical rather than commercial importance, since it represents the first attempt at distillation of bituminous sand in the McMurray area.

Fenton, J. T., P.O. Box 34, Salt Lake City, Utah. Canadian Patent 212908; U.S. Patents 1394481, 1396173, 1396174, 1409388, 1424998, 1432170, (1920-23).

The Fenton process was designed primarily for distillation of coals. The inventor considers that, with certain modifications, it can be adapted to the distillation of oil-shales and bituminous sand.

The apparatus consists of a vertical, cylindrical retorting-chamber, provided with suitable charging and discharging devices. The oil vapour

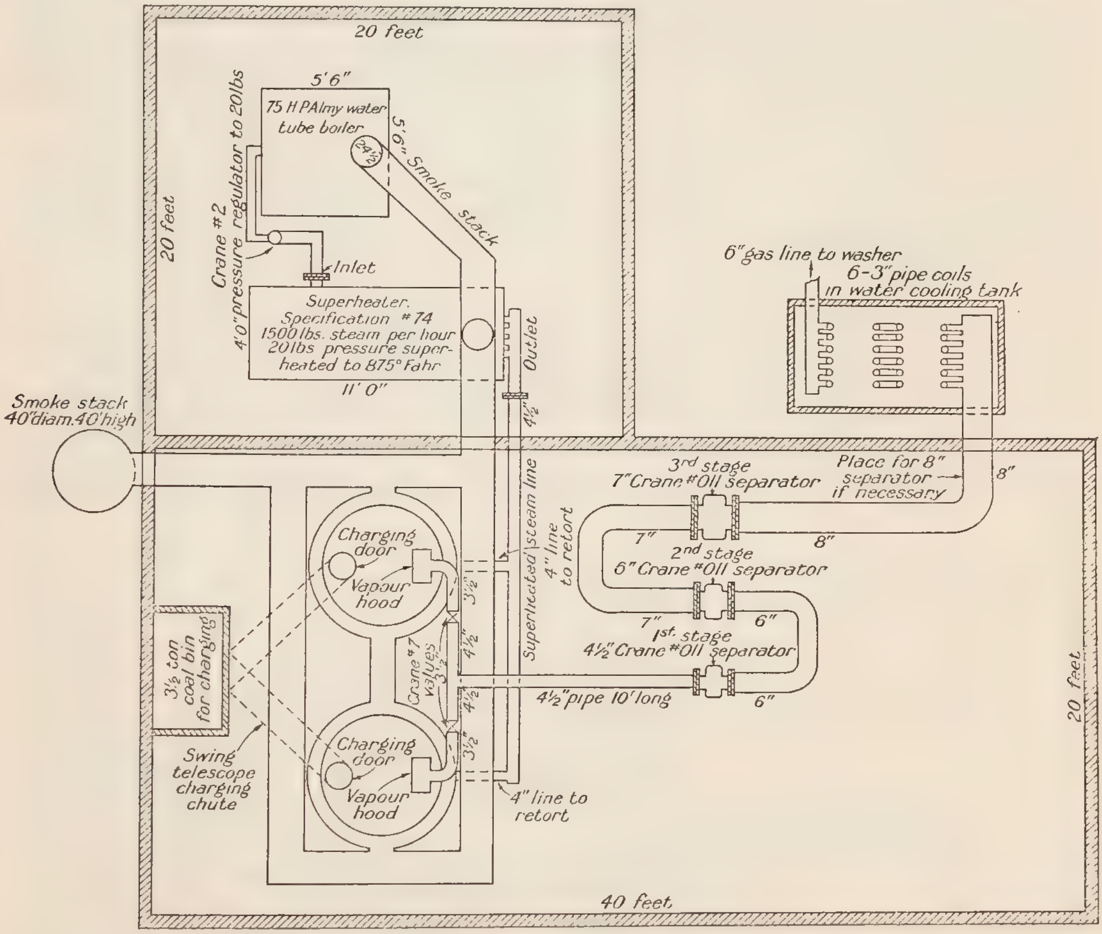

Fig. 23.—Ground plan of distillation process, J. T. Fenton.

line is designed as an expansion zone, condenser system, equipped with float-controlled, choke-valve outlet traps, and leads to a water-cooled condenser. Expansion stages may be modified as desired.

Distillation is effected through the medium of steam, superheated to 750° to 800° F., and under 10 to 20 pounds pressure. Distillation products are removed from the retort immediately they are formed, and it is claimed that formation of heavy hydrocarbons is prevented.

Operation of retorts is intermittent. Heat recovery is effected by arranging retorts in units of three, normal steam being passed through a

retort in which distillation has just been completed, and thence to preheat material in a newly charged retort.

A very complete experimental unit, (Figure 23) designed primarily for the distillation of coals, and having a charged capacity of one ton per charge has been erected in Salt Lake City. It is said that the sum of approximately $12,000 has been expended in developing and demonstrating the Fenton process.

Fenton, J. T., P.O. Box 34, Salt Lake City, Utah. Canadian Patent 212908, (1921).

The apparatus is designed for the treatment of bituminous sand, by subjecting the crude material to the action of superheated steam. As shown in Figure 24, bituminous sand is introduced through feed-opening (1),

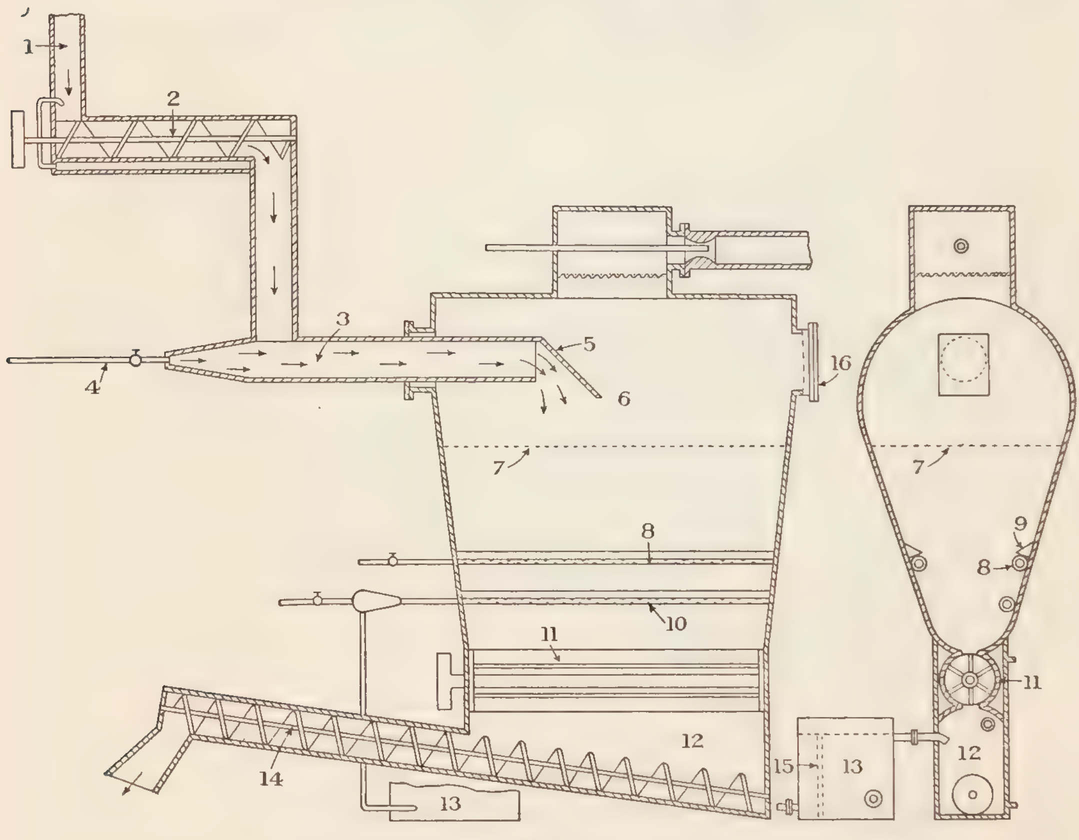

Fig. 24.—Apparatus for treatment of bituminous sand, J. T. Fenton.

and is propelled through steam-jacketed preheater (2), to a point of discharge leading to tubular inlet (3). Steam from jacket of preheater (2) may be conducted to feed-opening (1). Steam, superheated to a temperature of 700° to 1000° F., and under a pressure of 60 to 100 pounds, is introduced through pipe (4) into tubular inlet (3) and propels the preheated bituminous sand past baffle (5) and into chamber (6). In this chamber, the approximate level of material undergoing treatment is indicated as at (7). If desired, bituminous sand may also be introduced into chamber (6) through opening (16).

Superheated steam, under a pressure of 60 to 100 pounds, enters chamber (6), through perforated pipe (8), which is protected by a projecting fin or plate. At a somewhat lower point in chamber (6) heated water is introduced through a second perforated pipe (10), the perforations being chiefly on the lower surface in order to project the water in a downward direction.

From chamber (6) the thoroughly digested bituminous sand passes through rotary cylindrical-pocketed member (11) into steaming-chamber (12). From this chamber, separated hydrocarbons and water are withdrawn to chamber (13), and spent sand is discharged by conveyer (14). From the main body of chamber (13) the liquid hydrocarbons overflow into cell (15), the water being returned into chamber (6) through perforated pipe (10).

Vapours are withdrawn from the upper part of chamber (6), through a restricted vapour line and conducted to a condensing-system. This system includes a separator from which heavy oils, and fine mineral matter are drawn off. Uncondensed vapours then pass to a series of condensers which are maintained at successively decreasing temperatures.

Ferromastic Mining Company, Woodford, Okla., (1911-13). (Figure 25).

Hard bituminous sandstone, carrying 10 to 12 per cent bitumen, was treated in a series of four jacketed tanks, filled with heated water at a temperature of approximately 212° F. Rock from the quarry was sledged and fed into No. 1 tank. Here disintegration was effected through the action of a heavy blade propeller (1), which also served to propel waste

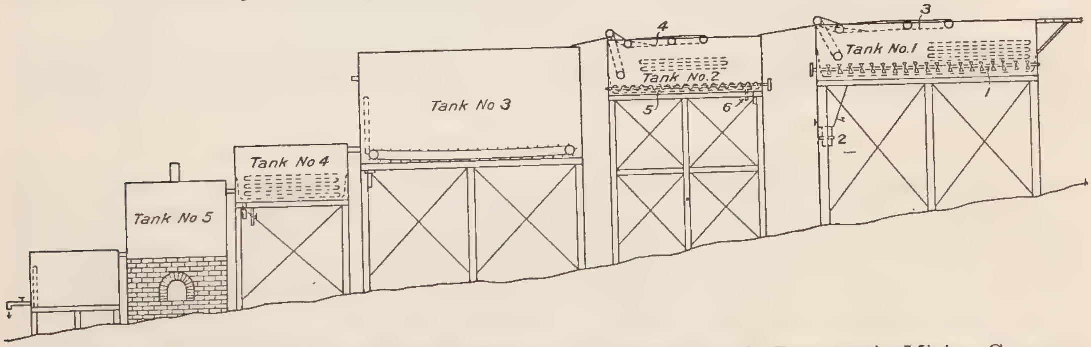

Fig. 25.—Outline of process for separation treatment of bituminous sand, Ferromastic Mining Company.

sand to a discharge opening (2). From the surface of No. 1 tank, a mechanical skimmer (3) carried a mixture of 25 per cent bitumen, combined with 75 per cent sand and water, to No. 2 tank, which was practically a heated settling-tank. From it a 50 per cent product, containing 10 per cent sand and 40 per cent water, was discharged by a skimming-device (4), while a screw-conveyer (5), carried the precipitated sand to a core valve discharge (6). No. 3 was also a settling-tank, in which the product from the preceding tank was allowed to cool, the water being drawn off from a point near the top, the bitumen at an intermediate point, and the sand removed by means of a mechanical scraper. Steam coils about the point of discharge, facilitated the drawing off of the bitumen. The bitumen product from this No. 3 tank contained approximately 20 per cent

of sand and water, and passed to tank No. 4 which was steam-jacketed and fitted with steam coils. In it a temperature of 300° F. was maintained. From this tank, the bitumen was drawn off from a point above the sand line, and run into No. 5 tank where direct heat raised the temperature to 450° F. It is said that at this temperature practically all the remaining sand settled out.

The throughput of the above plant was 40 tons crude rock per 10 hours with a production of 3½ tons of refined bitumen. Principal mining and separation costs were approximately as follows:—

Quarrying costs—		
6 men breaking and picking at $1.75	$10 50	
2 men drilling at $1.25	2 50	
Explosives	3 75	
		$16 75
Separation costs—		
1 fireman	2 00	
1 engineer	2 00	
1 separation man	1 75	
1 refiner	1 50	
1 foreman	2 50	
8 cords wood	16 00	
Incidentals	1 25	
Barrels	0 60	
Depreciation (15 per cent)	0 45	
		28 05
Actual cost of 3½ tons refined asphalt at refinery		44 80
Cost per ton (2,000 pounds)		$12 80

Fyleman, Ernest, 12 Egmont Road, Sutton, Surrey, England. English Patent 163519; Canadian Patent 203676, (1920).

In a contribution to the Society of Chemical Industry, January 31, 1922, Vol. XLI, No. 2, pp. 14T-16T, Dr. Fyleman outlines the theory embodied in the process.

It is evident that a satisfactory solution of the problem must provide for two conditions, firstly that the bituminous coating of the mineral particles shall be sufficiently fluid to flow freely, and secondly the provision of an economic and technically convenient method of overcoming the molecular adhesion between the two phases. The relations governing phase distribution between the solid and two liquids, all mutually insoluble, have been well handled by Reinders (Kolloid-Zeits., 1913, 235).

Let us consider a rock, R, coated with an oil, O, and let us now add to the system an aqueous solution, A. Let the interfacial surface tensions be σ RO, σ RA and σOA respectively. Then a rearrangement of the phases will occur when the total energy of the system is thereby reduced and not otherwise, that is when the sum of the surface energies of the new interphase surfaces is less than the surface energy of the old interphase surface which is eliminated. Therefore when $\sigma \text{RO} > \sigma \text{RA} + \sigma\text{OA}$ rearrangement will occur, the oil will be sheared off, so to say, from the rock surface, which will be wetted by the aqueous solution and freed from all contact with the oil. It would therefore be expected that the mineral particles would be absolutely clean.

From the above statement it is clear that an aqueous solution is required of low surface tension, something which froths readily, such as a solution of an alkali soap, of the alkali salt of a weak organic acid, or of saponin. Any of these solutions actually effects the desired result; in the case of a liquid mineral oil the change takes place in the cold; where a semi-solid bitumen is present it is necessary to render it sufficiently fluid either by warming or by adding a small quantity of a solvent such as petroleum oil. Very small concentrations of the water-soluble reagent are required, one part per thousand of water usually being ample. The physical rearrangement is very rapid.

and only requires sufficient mechanical agitation to ensure that all the particles come into contact with the aqueous solution. As most bitumens and many crude petroleums contain small amounts of compounds of weakly acid character, it is frequently sufficient to add to the water a very small amount of alkali such as soda ash (Ernest Fyleman, Eng. Pat. 163519/1920; Canadian Pat. 203676/1920). Thus the most convenient method of treating Alberta tar sand is to warm it to 80° C. or over, with a solution of one part per thousand of sodium carbonate in water, with gentle stirring. Segregation rapidly occurs into white particles of sand and small aggregates of bitumen, which ball together into larger masses on stirring and cooling slightly. The aqueous liquid can be used indefinitely to repeat the process with fresh quantities of tar sand, and the sand particles, which are very fine, can be flushed away through a coarse sieve, or separated by any of the usual hydraulic separating devices, leaving practically pure bitumen together with about 10 per cent of water, which it loses on heating. The same effect is produced on warming with a dilute solution of soap or of saponin. If a mixture of crude mineral oil and sand be stirred with dilute soap solution the oil is liberated and can then be separated; in practice, this process could be arranged to be continuous.

Dr. Fyleman's article also furnishes an estimated cost of treatment, together with power and heat requirements.

Gavin, M. J., and Bowie, C. P., U.S. Bureau of Mines, 506 Custom House, San Francisco, Cal. Canadian Patent 202622, (1922). (Figure 26).

This process was designed primarily to overcome the difficulties involved in the commercial distillation of well petroleum containing unduly high percentages of water, sand, and silt.

As stated in the patent specifications, the object is

To provide a process and apparatus whereby previously mentioned viscous pure or impure hydrocarbon-containing materials may be destructively distilled to produce fluids of fluidity sufficient to render them amenable to the usual methods of transporting or refining petroleum products. A further object of our invention is to provide an apparatus and means for distilling oil or bituminous shales and similar hydrocarbon-containing materials.

It is proposed to incorporate with the original petroleum, additional inert material—such as coal, peat, crushed shale, sand or diatomaceous earth—in such amounts that, when distillation is subsequently effected the non-volatile residuum in the still will be of a friable and non-caking nature, such as may be automatically and continuously discharged from the distillation chamber. Moreover, if the inert material is properly selected, water associated with the hydrocarbons to be distilled, vapourizes quietly and without excessive frothing. The mixed condensate, consisting of water and liquid hydrocarbons, may then be readily separated in settling-tanks.

When distillation is complete, the dry friable residue may be regenerated for further use by igniting it either with or without a separate destructive distillation of the residue, the combustible portion of the residue being consumed during the igniting operation. If the porous or earthy material added, be carbonaceous in its nature, it may subsequently be used for heating. If it be an non-combustible substance, it will after ignition be recovered in substantially its original form. In Figure 26 is shown an elevation of the apparatus partly in section, and a plan partly in section. In this figure (1) is a conical shell or retort, to the bottom of which are secured a series of lugs (2), which in turn are secured to plate (3) by means of bolts. An arm (4) carrying rabbles or scrapers, and

having at each end discharge gophers (5) rotates above plate (3). Divided solid material is fed through hopper (6), and vapour lines (7, 8 and 9), are provided at different elevations. Baffles or troughs (10, 11, 12) are secured to the inner walls of shell (1). These slope toward the vapour offtakes so that any condensate will be discharged through vapour lines. Pipe (13) is the oil inlet.

The distillation retort is set above a furnace in which either solid fuel, or fixed gases from the retort, may be burned.

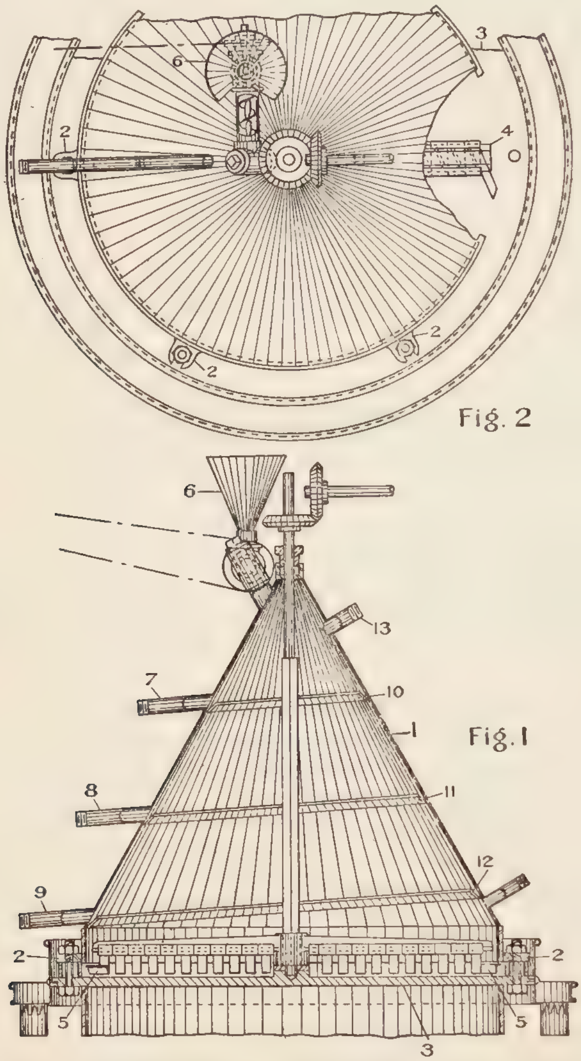

Fig. 26.—Apparatus designed for distillation of hydrocarbons, M. J. Gavin and C. P. Bowie.

In operation, plate (3) is externally heated to a temperature of from 200° C. to 250° C., being hotter near its periphery than at the centre. Arm (4) is rotated in a counter clockwise direction, and the divided solid material fed through hopper (6) on to plate (3). The oil, or similar hydrocarbon-containing substance, is introduced through pipe (13), falls on plate (3), and is there mixed with the divided solid material by the

rabbles or scrapers. As the non-volatile residue is moved toward the periphery of the plate, it reaches zones of increasingly high temperatures at which destructive distillation is completed and is discharged as dry, friable material.

In 1922, an experimental retort such as is referred to above, was erected in San Francisco by Messrs. Gavin and Bowie, of the U.S. Bureau of Mines, and between May 25 and July 29, a number of trial runs were conducted. The results obtained were encouraging, but in some respects, inconclusive. Probable costs of commercial operation cannot be deduced from data available at the present time.

The retort referred to above is the property of the U.S. Bureau of Mines, and in May 1924, was available for experimental work in connexion with distillation of bituminous sand.

Georgeson Extraction Process, Calgary, Alberta. Canadian Patent 245317.

The Georgeson process depends on introducing steam or heated water through pipes, and separating, in situ, hydrocarbons associated with the bituminous sand.

In January, 1923, a boiler together with the necessary piping was installed on Hangingstone river (L.S. 12, sec. 10, tp. 89, range 9), and a preliminary test was made by introducing steam into a sealed horizontal cavity excavated in an exposed face of bituminous sand. Subsequently (January 1924), a somewhat more elaborate test was undertaken on Horse river (L.S. 15, sec. 8, tp. 89, range 9). (Plate XLIII.) Of necessity the site selected was not favourable since, instead of a heavy impervious capping, the bituminous sand was overlain by approximately 15 feet of sand and gravel. As drilling equipment was not available, three shafts were dug to the bituminous sand. Steam pipes were then driven to a point near bed-rock (Devonian limestone), and the shafts filled and tamped. The shafts formed the apexes of a triangle of which the sides were approximately 65 feet, 55 feet, and 55 feet in length.

Steam was then turned into each of the three pipes and held at a pressure of 90 pounds for a period of approximately 12 hours. The pipes were then raised about 10 feet, steam again introduced for a further period of 8 hours, and finally 4-inch casing was driven to the zone within which the action of the steam had been effective. On opening the gate valve in the casing, it is stated [1] that a mixture consisting of oil and water, was thrown to a height of approximately 30 feet above the casing-head. The 4-inch casing was then lowered to a point near the bottom of the cavity that had been chambered out, and a mixture of sand and water recovered. The sand was practically free from bitumen, indicating the effective action of steam when introduced into unaltered bituminous sand.

It is proposed to carry out further tests of the Georgeson process early in 1926.

[1] Dr. George A. Ings, McMurray, Alta.

In view of the fact that the above process is, in some respects, analogous to the so-called Frasch Sulphur process, as developed in the Gulf Sulphur field, the following reference is of practical interest.[1]

Extensive deposits of sulphur occur in Texas, at a number of points adjacent to the Gulf of Mexico, and commercial development has been undertaken by the Texas Sulphur Company near Gulf, Texas; by the Freeport Sulphur Company at Bryan Mound and Hoskins Mound, near Freeport, Texas; and at Sulphur, Louisiana. The success which has attended this development is due to the adaptation of the Frasch process.

The Gulf Coast region is noteworthy for the occurrence of domes of slight elevation and up to 4,000 feet in diameter. In drilling through these structures for oil, sulphur was found in certain localities. Although geological sections vary at different points, a typical descending section indicating the general nature of strata underlying the domes includes:—

Unconsolidated sediments (consisting of shales, gumbo, boulders, etc.)	700 to 1,000 feet
Cap rock (consisting chiefly of porous limestones)	2 " 40 "
Porous limestone (containing irregular bodies of sulphur)	70 " 110 "
Anhydrite and rock salt	5 " 50 "
Rock salt	

The greater part of the sulphur occurs in strata that are generally horizontal, but, towards the margins of domes, dips increase to angles exceeding 45 degrees. As the dip increases, the sulphur-bearing strata tend to thin out.

The application of the Frasch process consists in melting the sulphur (melting-point 235°F.) in situ, by heated water introduced under pressure through vertical pipes, and subsequently forcing the liquid sulphur to the surface by means of pumps or air-lifts. The sulphur is then piped to central stations, whence it is pumped into large wooden rectangular forms where it solidifies. Subsequently the wooden forms are removed, the sulphur broken down by the use of explosives, and loaded on railroad cars by steam shovels.

Each well drilled for the recovery of sulphur, presents an individual problem, but general practice may be briefly described as follows. (Figure 27).

A well, 8 to 10 inches in diameter, is drilled through overlying sediments to the top of the cap rock and cased. A bore of smaller diameter is then continued to near the bottom of the sulphur-bearing strata, and cased with 6-inch pipe. Near the lower end of the 6-inch pipe and on its inner surface, an annular metal seat is provided, and the pipe itself perforated for a distance of 3 feet, more or less, above and below, so as to permit free circulation of liquids. Within the 6-inch pipe and concentric to it, a third pipe 3 inches in diameter is introduced.

This pipe is provided with a flange near its lower end, forming a tight seal with the annular ring on the 6-inch pipe, the lower end of which is left open. Within the 3-inch pipe, a 1-inch pipe is placed concentrically, and extends to within 10 or 20 feet of the lower end of the 3-inch pipe. Water is pumped down through the annular space between the 3-inch and 6-inch pipes, and passes out through perforations in the 6-inch pipe above the seal.

[1] Davis, Harold S: The Sulphur Industry of Today. Can. Chemistry and Metallurgy, Vol. V, Oct. 1921.

In operation, water under approximately 90-pound pressure, and at a temperature of approximately 320° F., is forced down between the 1-inch pipe and 3-inch pipe, and also between the 3-inch pipe and 6-inch pipe, and circulates freely by means of the perforations provided. From 12 to 24 hours is required to heat the sulphur-bearing stratum adjacent to the lower end of the bore to a temperature at which sulphur will flow. The supply of water entering through the 3-inch pipe is then cut off, but continues to descend through the annular space between the 3-inch and 6-inch pipes. At the same time compressed air, under a pressure which varies up to 500 pounds, depending on local conditions and depth of well,

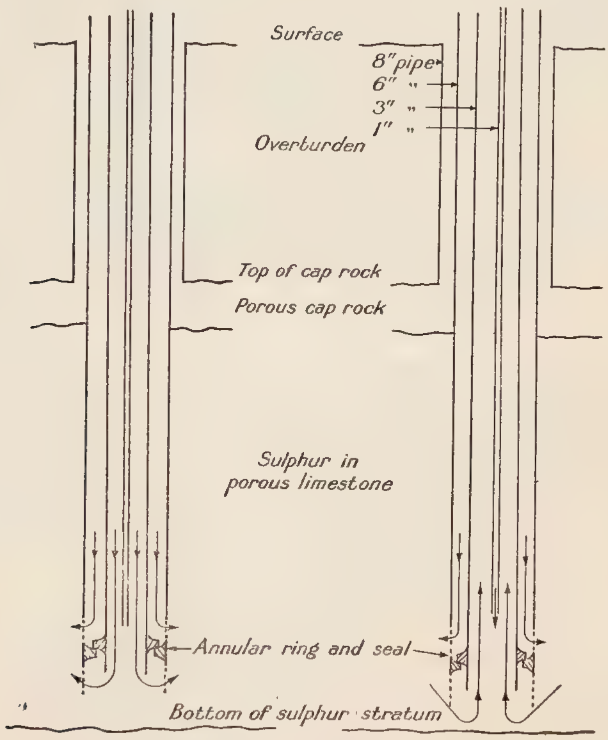

Fig. 27.—Method adopted for recovery of sulphur in situ. First phase, water flowing through annular space between 6-in. and 3-in. pipes and between 3-in. and 1-in. pipes. Second phase, water flowing through annular space between 6-in. and 3-in. pipes, sulphur returning through 3-in. pipe, air pressure through 1-in. pipe.

is introduced through the 1-inch pipe. The melted sulphur (sp. gr. 1·8) flows to the bottom of the bore and is forced to the surface through the 3-inch pipe.

As the sulphur rises, water in the 3-inch pipe is also forced to the surface. In order, however, to prevent excessive pressure in the sulphur deposit itself, the great bulk of the water pumped into the wells is removed through separate "bleed" wells, that are drilled at a distance from the sulphur wells proper.

The Frasch patents,[1] after running their full course of 17 years, expired in 1908. The process and apparatus which they covered then became public property under the provisions of the patent law. There are, in fact, only two fundamental requirements for the mining of sulphur by hot-water fusion. One is to pump down into the deposit an adequate volume of hot water at a sufficient temperature to melt the sulphur and to keep it melted. Another is to raise the sulphur out of the well by what Frasch calls "a pump or pumps" or "other fluid-moving means," including "any known or suitable substitute for a pump." With the apparatus which is provided in these expired patents, hot water can be pumped down into the deposit in ample volume and at the requisite temperature, and, when the sulphur is thus reduced to liquidity, it can be pumped out.

Instead of the sucker-rod pump an ordinary air lift was subsequently used. It was a second-hand air lift, bought for the purpose, and, when inserted in place of the sucker-rod and its various adjuncts, it operated, as might have been expected, without a hitch. Whether the sucker-rod pump was used or the air lift, the mode of operation was necessarily the same, in that in both cases the hot water forced into the sulphur deposit melted the sulphur, and the pumping devices (i.e., the sucker-rod pump or the air lift—both of which were common expedients for raising liquids from great depths in the mining industry) raised the liquid sulphur to the surface.

Almost at the end of the term of the expired Frasch patents, the Patent Office nevertheless issued additional patents to Frasch, assuming to give him a monopoly of the use of an air lift as the means of raising the melted sulphur from the deposit; but an appeal in the case of the Union Sulphur Co. vs. the Freeport Texas Co., in the U.S. Circuit Court, sitting at Philadelphia, resulted in a decision which insists that the patent in question lacks the essentials of an invention. The use of an air lift, therefore, involves no infringement.

Giger, Albert, 1621 Cotton Drive, Vancouver, B.C. Canadian Patent 238222, (1924.)

This process is designed for recovery, by distillation, of hydrocarbons from bituminous sand, bituminous shales and other solid bituminous materials. The apparatus is known as the Giger horizontal continuous-

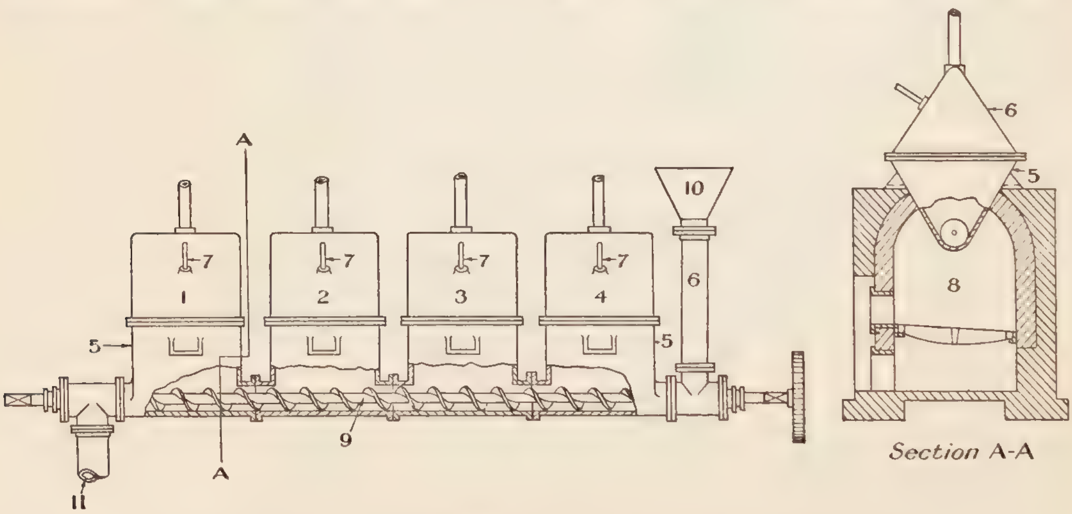

Fig. 28.—Apparatus for distillation of bituminous sand, Albert Giger.

[1] Eng. and Min. Jour. Vol. 107, No. 13. pp. 556-557.

United States patents covering Frasch process for mining sulphur are as follows:—No. 461,429, Oct. 20, 1891-Mining Sulphur; No. 461,430, Oct. 20, 1891-Apparatus Mining Sulphur; No. 461,431, Oct. 20, 1891-Mining Sulphur; No. 799,642, Sept. 19, 1905-Process of Mining Sulphur; No. 800,127, Sept. 19, 1905-Apparatus for Mining Sulphur; No. 928,036, July 13, 1909-Installing Wells; No. 977,444, Dec. 6, 1910-Apparatus for Mining Sulphur; No. 988,994, Apr. 11, 1911-Valves for Pipes which Convey Melted Sulphur; No. 988,995, Apr. 11, 1911-Mining Sulphur; No. 1,008,-319, Nov. 14, 1911-Improvements in Mining Sulphur; No. 1,152,499, Sept. 7, 1915.

feed retort, of which a longitudinal vertical section, and a transverse vertical section on line A-A, are illustrated in Figure 28. (1) (2) (3) and (4) indicate in general a number of retorting chambers, each of which consists of a lower casing (5), and an upper casing (6). Each casing is substantially V-shaped in section, is equipped with a pyrometer (7). Individual heating-furnaces (8) are provided below each of the retorting-chambers. A gear-driven conveyer shaft (9), equipped with suitable journals and stuffing-boxes, extends through the lower portion of the retorting-chambers. Feed hopper (10) and discharge (11) for spent sand, are provided.

In operation, bituminous sand or other material to be distilled, is propelled through the series of chambers, and is subjected to progressively higher temperatures. Oil vapours are withdrawn from individual temperature zones through suitable offtakes.

In 1923, a small model plant comprising a four-compartment retort, was constructed in Vancouver, B.C. It is claimed that flexibility and continuity of operation, automatic temperature control, and low power consumption are favourable features. It is proposed to erect a semi-commercial unit during the present year (1925).

Ginet, J. H., 720 Symes Building, Denver, Colorado. Canadian Patent 222951, (1923).

A single commercial unit of a Ginet retort, consists essentially of a horizontal metal cylinder, 3 feet in diameter and 20 feet in length. A series of scoops, attached by arms to a shaft passing through the retort,

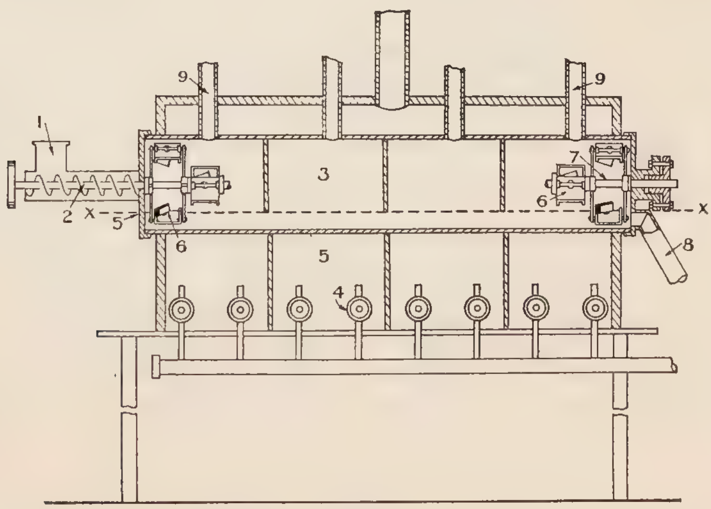

Fig. 29.—Apparatus for distillation of bituminous sand, J. H. Ginet.

agitate the charged material and propel it to a point of discharge. The heating-furnace is of special design.

It is claimed that distillation conditions within the retort are favourable to high recovery of hydrocarbons, and that flexibility of operation and adjustment permit of distillation of various types of oil-shales and

oil sands. In 1923, a single Ginet unit of commercial size was erected near De Beque, Colorado, but so far as the writer is aware, has not yet been used for the commercial treatment of bituminous sand.

In 1924, two small experimental units were installed by the Western Securities Corporation, at 1688 Papineau Ave., Montreal. Inside diameters of these retorts are 8 inches and 18 inches respectively, and inside lengths are 2 feet 7 inches, and 6 feet 7 inches. Actual throughput capacities have not been accurately determined.

In April, 1925, the writer witnessed a demonstration of the Ginet process in Montreal. Bituminous sand is introduced at (1) (Figure 29), and propelled by screw-conveyer (2) into retorting-chamber (3), heated by gas from burners (4) in firebox (5). While undergoing distillation, the bituminous sand is propelled through the retort by a series of specially designed scoops (6), attached to revolving-arm (7). These scoops also serve to keep the inside surface of the retort free from coke, and to constantly agitate the bituminous sand. Spent sand is discharged at (8), and oil vapours are withdrawn at offtakes (9) to a condenser. Uncondensed gases are piped to firebox (5) and burned.

Results of the demonstration in Montreal were not conclusive since the capacity of the condenser was inadequate. Retorting temperature was approximately 950°F.

Hampton, Wm. Huntley, 475 West Park St., Portland, Oregon, (1925).

The method adopted in the Hampton process, consists in disintegrating and scouring the bituminous sand in the presence of a warmed petroleum fraction, such as kerosene. The semi-fluid product passes to a classifier or deliquidizing machine of the Dorr type, where it is further treated by a "wash oil." From the classifier the partly leached sand passes for final treatment to a continuous vacuum filter of the Oliver type or to a centrifuge of the Elmore type. The waste sand as discharged, contains from 2 to 5 per cent of " wash oil " which is volatilized in a steam drier, and subsequently condensed. Heat is recovered from the heated waste sand by the introduction of a heat exchanger, and used to preheat solvent fractions required for the operation of the process, as well as the liquid hydrocarbon product recovered from the bituminous sand. The partly purified product from the classifier, consisting of "wash oils," separated bitumen and some finely divided mineral matter held in suspension, is introduced into a series of stills with recovery of the various petroleum fractions and asphaltic residuum.

Hartley, Carney, 720 Colorado Building, Denver, Colorado, (1919-22).

During 1919, Mr. Carney Hartley and associates erected in Rio Blanco county, Colo., a small retorting unit designed for the recovery of hydrocarbons from oil-shales and bituminous sand. Owing to difficulties in connexion with titles to mineral leases, and to other causes, the work was discontinued, and a second plant erected in Routt county. The first trial run was made on December 1, 1919, and the plant was further

perfected during 1920-21. Pending completion of further experimental work the probable commercial value of the process cannot be definitely asserted.

Distillation is effected in an enclosed vertical metal tube, 24 inches in diameter, equipped with a rotating conveyer device for regulating movement of charge through retort. Oil vapours are removed to condensers through multiple offtake pipes. It is claimed that advantages of the system are heating efficiency, simplicity of construction, and a minimum of working parts.

It is stated that experimental work has represented an expenditure of approximately $45,000.

Kelsey, A. F., Vermilion, Alberta. U.S. Patent 1514162, (1924).

This process is designed for the separation of bitumen from bituminous sand, and similar materials, by the use of an aqueous or other solution. So far as possible, the use of moving parts has been avoided.

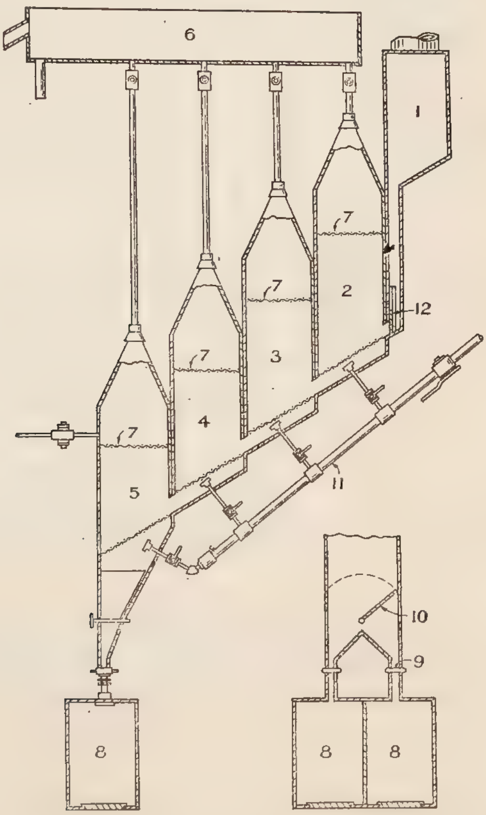

Fig. 30.—Apparatus for separation treatment of bituminous sand, A. F. Kelsey.

Figure 30 illustrates a sectional elevation of the apparatus. Principal features of the apparatus comprise a hopper (1), a variable number of separation chambers as (2, 3, 4 and 5), and overflow tank (6). Screens with openings ranging up to 1 inch, are provided at bottoms of

separation chambers, and other screens (7), with openings of approximately ½ inch, are arranged at a somewhat higher level; (8) is a container for waste sand, passages connecting with separation chambers being equipped with valves (9), and movable shutter (10).

In operation, steam or hot compressed air, is introduced through pipe (11) into the lower portion of separation chambers (2, 3, 4 and 5). The solution—such as brine—is brought to the desired level, and the sliding gate (12) is raised to admit the preheated bituminous sand. In the first separation chamber (2), a portion of the bitumen rises to the surface of the water, and the partly leached sand falls through the screen and passes on successively to chambers (3, 4 and 5). The bitumen rises to the surface of the water, is collected in tank (6) and withdrawn as desired.

In conducting his experimental work, Mr. Kelsey has made use of water, brine, and kerosene and it is stated that satisfactory results have been attained.

Kohler, H., Berlin, Germany. German Patent 204256, (1908).

This process was originally designed for the treatment of montan wax[1], but it is claimed that it may also be adapted to the treatment of bituminous sand.

Separation depends on the use of a solvent with a low boiling-point such as impure naphtha. The solvent is subsequently recovered by distillation.

Leonard, Geo. I., 1232 Marquette Bldg., Chicago, Ill.

No information is available regarding method contemplated for the treatment of bituminous sand.

Lindsay, Major General W. B., 9 Bank of Montreal, 64 Wall St., New York.

The process is based upon the direct application of a heating medium to the substance to be treated, and the selective fractional condensation of the resultant vapours. It is a continuous process, and automatic in its action.

In connexion with the investigation of the above process, it is stated that research and experimental work have involved an expenditure of more than $400,000. It is considered by those in charge of the investigation, that the process is technically a success, and that the perfection of mechanical apparatus will permit of its commercial application.

McMurray Asphaltum and Oil, Ltd., Petrolia, Ont. Canadian Patent 230423. (Figure 31.)

The process is designed for the treatment of bituminous sand, with recovery of liquid or semi-solid hydrocarbons. Distillation—or separation as desired—is effected in a horizontal, cylindrical, gear-driven drum, mounted on trunnions and heated from below. Two sets of gears are

[1] See also German Patents 101373, 116453, 260697, (1911) "Braunkohlenteer-Industrie," Halle, 1908.

provided, and during the period of distillation, the drum is rotated at relatively low speed. If, however, it is desired to clean the drum, higher speed of rotation is possible by the second set of gears. Oil vapours are withdrawn through a hollow trunnion, to a condenser.

In Figure 31, an enclosure or pit (1), is provided with metal doors, within which the drum (2) is installed. Above this pit are cover plates (3) and (4), through which passes a charging-spout (5), and the upper of which serves as a charging-platform. Products of combustion from the firebox, pass through the space between the two plates, and thence to the stack.

In the shell of the distillation or separation drum (2), one or more manholes, provided with suitable cover plates, are arranged for charging and discharging. Agitating devices (6), having a somewhat free move-

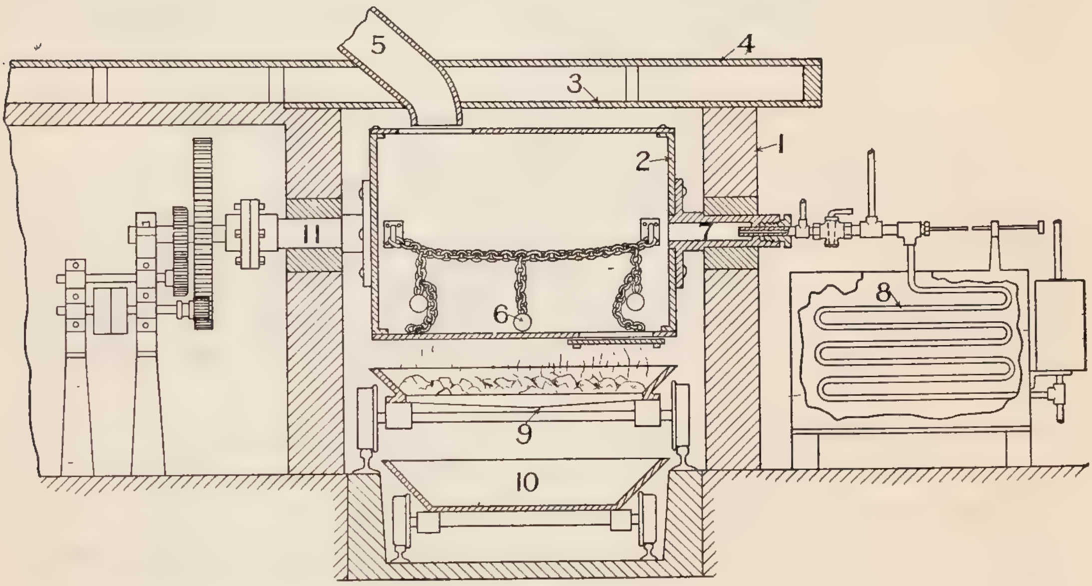

Fig. 31.—Apparatus for separation and distillation treatment of bituminous sand, McMurray Asphaltum and Oil Co., Ltd.

ment, and hammer-like action, assist disintegration and prevent coking. Oil vapours are withdrawn through a hollow trunnion (7) to a condenser (8).

Below the drum is a metal car (9), on standard gauge track, which serves as a movable firebox. When the drum is to be discharged, the car is withdrawn, and hot spent sand falls into a second car (10) operated on standard gauge track at a somewhat lower level.

If it is desired to produce liquid hydrocarbons, distilled oil vapours are withdrawn to the condenser. If, on the other hand, bitumen in a more or less unaltered form is to be separated from the bituminous sand, the drum is partly filled with water. When charged, the water level should reach the centre of the offtake in trunnion (7). Under the action of the heated water, combined with agitation, a mixture consisting of bitumen and fine sand, rises to the surface and is drawn off, its removal being assisted

by a jet of steam or air introduced through trunnion (11). As this sand-bitumen mixture is discharged, it is washed with jets of warm water, and further purified. It is stated that the product derived in this manner contains from 10 to 12 per cent of the finer sand, all of which will pass a 100-mesh screen.

The first small experimental unit was constructed by the Draper Manufacturing Co., of Petrolia, in October 1920, but during the winter of 1921-22, two larger units, each having a capacity of approximately 4 tons of bituminous sand, were completed. These, with other necessary auxiliary equipment, were installed at Waterways, Alberta, during the summer of 1922, and were operated intermittently during 1922 and 1923. It is stated that the financial outlay up to October 1924, amounted to not less than $35,000. In August, 1924, a portion of the plant was destroyed by fire. Necessary reconstruction is now completed however, and it is expected that operations will be resumed in 1925.

Meyer, Emil, Berlin, Germany. German Patent 99566, (1898).

This process was originally designed for recovery of liquid hydrocarbons from lignites and similar materials. It is claimed that it may also be adapted to the treatment of bituminous sand. Moisture is first removed by treating the crushed crude material with alcohol, after which a mixture of alcohol and benzine or other suitable petroleum distillate is introduced. Provision is made for recovery of the solvent by distillation.

Murray, S. R., and McDermand, G. E., Denver, Colo. U.S. Patent 1060010, (1913).

The process is based on the action of a solvent, such as a petroleum distillate, in leaching bitumen from bituminous sand or other similar material.

In Figure 32, (1) is an oval-shaped metal retort, having a cover or hood (2), the edge of which rests in a liquid seal. A filtering medium is enclosed between perforated plates (3) and (4), and below this is a space (5), equipped with a steam-heated coil (6). From the hood (2), an offtake pipe leads to a coil condenser (7), equipped with valves (9), (10) and (11), which in turn has a pipe connexion with a storage tank (8). Storage tank (8) is also connected with the lower part of retort (1).

In operation the hood of the retort is temporarily raised, a charge of bituminous sand introduced into the retort, and a quantity of solvent introduced from storage tank (8). Steam having been turned into coil (6), the solvent is volatilized, and rises through the charged retort, passing on into condenser (7), valves (9) and (11) being closed. The condensed solvent then returns by gravity to retort (1), and passing through the charge, leaches out associated bitumen. Heat is again applied to the solvent-bitumen solution, and valve (10) being closed while valves (9) and (11)

are open, solvent vapours condense in condenser (7), and flow into storage tank (8). Bitumen is then withdrawn at offtake (12), and the process repeated intermittently.

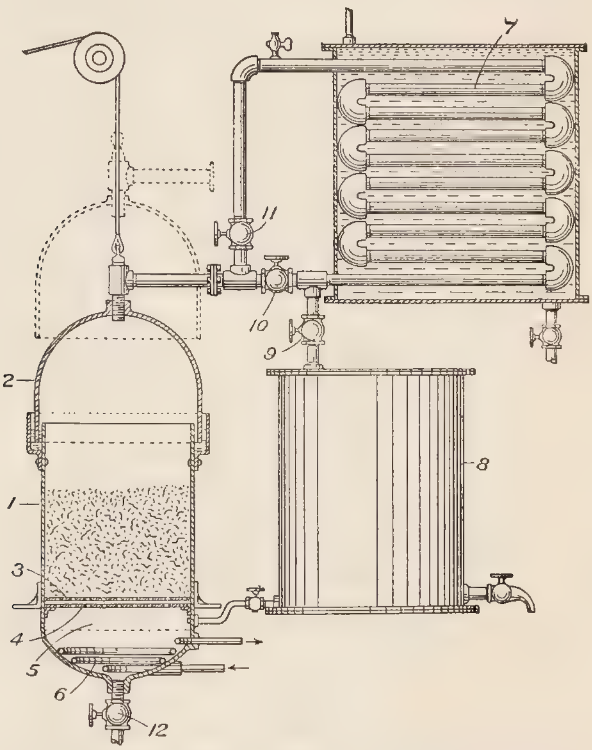

Fig. 32.—Apparatus for separation treatment of bituminous sand, S. R. Murray and G. E. McDermand.

Oil Exploitation Corporation, 100 Broadway, New York.

In 1922 the above corporation erected a demonstration plant near Taber, Cal., with a capacity of approximately 50 tons bituminous sand per 24 hours. Crude bituminous sand entered a steel tank, equipped with a heavily constructed cutting and mixing flight-conveyer. Super-heated steam at 700° F. was introduced and accelerated the rate of disintegration.

The disintegrated pulp flowed freely to a series of hot water flotation cells, where part separation was effected. The partly separated product then passed through a second set of similar cells for final treatment, while the partly leached sand tailings were dewatered by a drag-belt, and passed through a settling-compartment. The sand tailings, as finally removed, were free from bitumen.

The above plant was not in operation at the time of the writer's visit in November, 1923, but it is claimed by those in charge that a bitumen, 99 per cent pure was produced. Mr. James McEvoy, of Toronto, Ont., reported on the process in December, 1922.

Pacific Oil and Asphalt Co., San Francisco, Cal.[1]

A somewhat comprehensive investigation was undertaken by the above company prior to 1903, with a view to recovering bitumen from the bituminous sands and sandstones of Santa Barbara county, Cal. Although the company did not erect a commercial plant, about $30,000 was expended in the construction of a small, well-equipped unit at San Francisco. The results were satisfactory as regards quality of product.

The bituminous rock was first sorted in order to bring the average content in bitumen up to 40 per cent, and then ground to pass a 30-mesh screen. The product was then heated to 250° F., fluxed, and run into barrels. The excellent quality of this natural material, in the preparation of which high temperatures were avoided, was recognized, but apparently production costs were too high to permit of competition with petroleum residuum.

The above reference is of interest, since an equally pure product can probably be produced from Alberta bituminous sand at reasonable cost.

Parker, J. E., Denver, Colo., (1922-23).

In 1922 a small unit was constructed in Denver, Colo., in order to demonstrate the operation of the Parker process. It is said that the experimental work represented an outlay of upwards of $50,000.

The process is mechanical, and consists of agitation of bituminous sand in heated water. Mechanical means are provided for removing spent sand and separated oils or bitumen.

The apparatus consists of a circular steam-jacketed tank, 12 feet in diameter and 6 feet deep, with a centrally arranged annular compartment 3 feet in diameter and 6 feet deep. The tank is mounted on rollers and revolves at the rate of 30 to 60 r.p.m. A series of specially designed centrifugal agitators (mounted on a stationary frame) are provided in one quadrant of the tank. As the tank revolves, the disintegrated sand passes through a quiet water zone from which it is removed by bucket elevator. Liberated bitumen is skimmed from the surface of the water and passes to dehydrator and storage.

The writer is advised that, owing to mechanical difficulties, the above process has been abandoned.

Philippi, J., New York; U.S. Patent 655416, (1900).

Bituminous sand is mechanically disintegrated in heated water, devices being provided for removing the separated bitumen and the waste sand. The operation is intermittent, a determined quantity of bituminous sand being introduced at one time. (Figure 33.)

Bituminous sand is charged through hopper (1) into the lower section of tank (2), and disintegrated by rotating beater (3). Water is maintained at any required temperature by steam introduced at intake (4)

[1] Engineering and Mining Journal, Oct. 3, (1903).

Separated bitumen, together with some fine sand and water, rises to the surface of the water, is removed by perforated skimming-blades (5), and discharged into an inclined trough. When separation is complete, the motion of rotating beater (3) is reversed, and the longer blades propel the sand residue into the boot of sand-elevator (6).

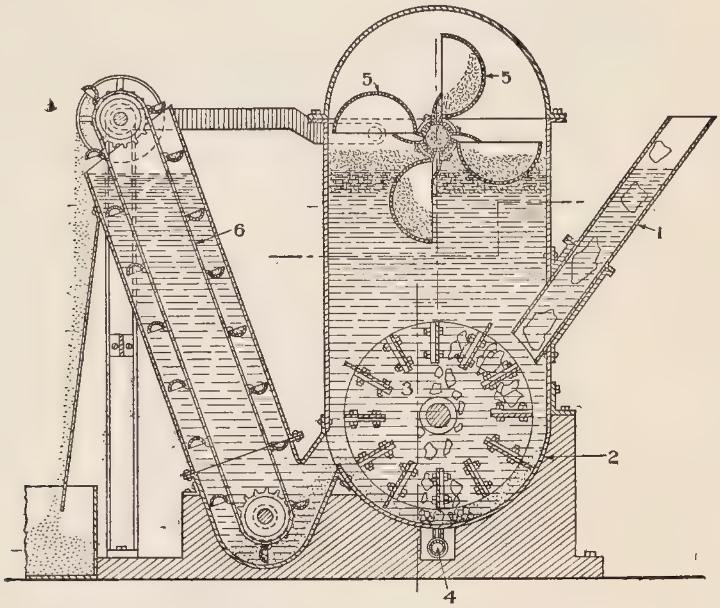

Fig. 33.—Apparatus for separation treatment of bituminous sand, J. Philippi.

Information available indicates that demonstration of the above process was not carried beyond small-scale experimental work.

Price, J. R., and Cook, C. L., San Francisco, Cal. U.S. Patent 1190633; Canadian Patent 194319.

During the period 1914-16, Mr. J. R. Price, late of the City Street Improvement Company, San Francisco, and Mr. C. L. Cook, Chief Chemist of the District of San Francisco, erected at Oakland, Cal., a small experimental separation unit, having a charged capacity of approximately 1,000 pounds bituminous sand. The primary aim was to establish a fundamental principle on which to base a separation process, mechanical perfection of apparatus at the outset being considered of secondary importance. Heated water was the separation medium employed, either with or without the addition of reagents.

In previous attempts to employ the heated water, separation had been conducted at atmospheric pressure, the temperature of the water being thus limited to approximately 212° F. Apart from the comparatively low temperature that could be attained, ebullition of the water tended to hold the finer sand and silt in suspension, and thus prevent efficient concentration of pure bitumen. It was proposed by Messrs. Price and Cook, to employ pressure in the separation chamber, thereby raising the boiling-point of the water to any desired temperature.

As noted above, mechanical operation of the apparatus had not been perfected, but the principal features are illustrated in Figure 34. The bituminous sand is introduced into chamber (1), (which is equipped with the necessary gauges), the opening closed by screw plug (2), and with valve (3) still closed, steam under boiler pressure is admitted at (4) and (5). Valve (3) is then opened, and the partly digested charge, under pressure, is admitted into separation compartment (6). Valve (3) is then closed, and a fresh charge of bituminous sand introduced into chamber (1). Hot water from the boiler is intro-

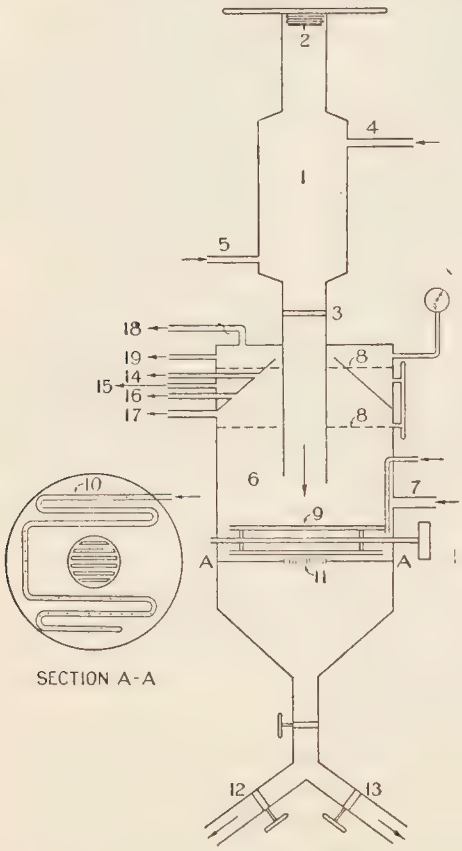

Fig. 34.—Apparatus for separation treatment of bituminous sand, J. R. Price and C. L. Cook.

duced at (7), the water level as at (8) being adjusted from time to time, as bitumen accumulates at the surface or is drawn off. Agitation of the bituminous sand is afforded by a belt-driven, 4-arm agitator (9), and by steam through perforated coils (10). When separation is complete the waste sand that has fallen through grating (11) is removed under pressure, by means of any suitable discharge, as alternate valves 12 and 13. Offtake pipes (14 to 17) are provided to remove bitumen from time to time as it accumulates at the surface of the water, the level of which may be adjusted as desired. A part of the bitumen may also be removed through pipes (18) and (19) which enter the separation

chamber at points above water level, the bitumen being lifted from 2 to 6 inches according to the pressure. Drawing off of bitumen is continued until pressure and temperature fall below a certain point, after which pressure is again restored, and drawing off repeated. The process is thus intermittent. Auxiliary equipment used in connexion with the experimental unit includes a 16 h.p. vertical water-tube boiler, and a 2 h.p. gasoline engine.

First cost of a plant, operated on principles outlined above, may be high, but operating costs would be low. Features open to criticism are intermittent feed and intermittent discharge, involving heat losses. Modification in mechanical design would reduce these to a minimum. The product also contains water, and a percentage of very finely divided mineral matter.

In 1916, the writer forwarded to Mr. Price, 400 pounds of Alberta bituminous sand. Unfortunately this sand had been mined 8 months previously, and results attained were not so favourable as could reasonably have been expected had freshly excavated material been used. Using this bituminous sand, a trial separation run was made on May 29, 1916. The temperature of water varied from 220° F. to 312° F. Owing to a mechanical defect, which resulted in insufficient agitation, some of the material lodged in corners, and was not properly leached by the hot water. About 51 pounds of the partly leached sand was therefore treated a second time. Results of the test may be summarized as follows:—

Total weight of bituminous sand treated	400 pounds
Associated bitumen	56 "
Total time of heating first charge	6¾ hours
Time of re-treatment of 51 pounds	5 "
Bitumen separated	49½ pounds
Purity of product	94 per cent

Shortly after the above test was made the investigation by Messrs. Price and Cook was discontinued.

The use of pressure apparatus undoubtedly introduces undesirable features. On the other hand, representatives of the J. P. Devine Co., of Buffalo, the Buffalo Foundry Co., of Buffalo, and Badger & Co., of Boston, consider that, as now perfected, pressure apparatus is being constructed which is found to be entirely satisfactory. As an illustration with which the writer is familiar, the pressure tanks used by the Utah Copper Company, in precipitating copper from acid solutions may be cited.

Ranney, Leo., (Liquid Mineral Products Company), Jacksboro, Texas. Patents pending (1924).

The object of the Ranney process is to recover, by means of shafts and tunnels, a greater percentage of petroleum from oil sands than is possible by present standard drilling and pumping methods. As opposed to the drainage methods adopted at Pechelbronn, oil is recovered through a system of piping. Pressure in the oil sands is obtained by re-establishing gas or hydrostatic pressure.

From present knowledge of conditions in the McMurray area, it appears that the above process would not be applicable for recovery of hydrocarbons associated with the bituminous sand. In areas where the bitumen is sufficiently fluid to flow at a temperature of 100° F., the process may have possibilities.

Robinson, M. A., Missoula, Montana.

Washing or leaching is resorted to for recovery of the hydrocarbon content of the bituminous sand. The essential feature of the process is the solution used, and this is protected by patent.

The bituminous sand is first crushed to the required size and delivered to a hopper bin. It is then conveyed through a steel trough or cylinder, (to which sufficient heat is applied to warm the sand in transit), to an enclosed steam-heated tank in which separation is effected. The capacity of this tank is such that approximately 5 tons of bituminous sand and 20 gallons of solution can be introduced at one time. After the tank has been charged, openings are closed, and the contents agitated by a centrifugal agitator for a period of approximately 10 minutes. Solvent carrying the bitumen in solution is then drawn off, and the solvent recovered by distillation and the partly cleaned sand is removed to a second tank for final separation treatment.

It is stated that San Rafael oil sands, treated by the above process, yielded approximately two barrels of hydrocarbon product per ton of sand treated, and that total costs will not exceed 75 cents per barrel.

Salathe, F., Jersey City, New Jersey. U.S. Patent 452764. (Assigned to the Litho-Carbon Company of New York, 1891.)

The process is based on the action of a solvent, such as a petroleum distillate, in leaching bitumen from bituminous sand or similar material.

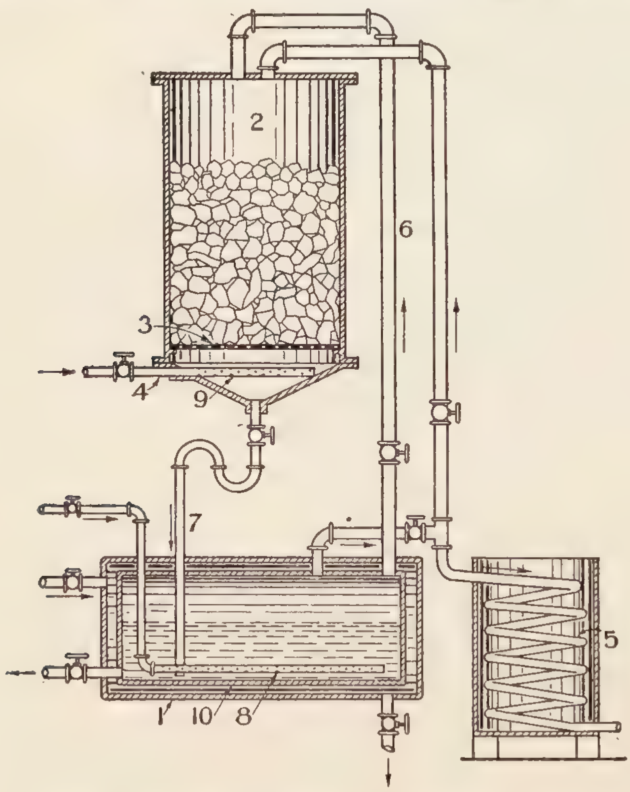

Fig. 35.—Apparatus for separation treatment of bituminous sand, F. Salathe.

A vertical section of the suggested apparatus is illustrated in Figure 35.

The essential features are a jacketed, solvent storage tank (1), a separation chamber (2), with perforated false bottom (3), and perforated steam pipe (4) and a coil condenser (5). In operation crushed bituminous sand or similar material is introduced into chamber (2), and steam turned into steam jacket (10) of tank (1). Solvent vapours rise through pipe (6), condense in chamber (2), and again descend to tank (1), carrying in solution the separated bitumen. During this time, condenser (5) is shut off from tank (1) and chamber (2). When separation is complete, valves in pipes (6) and (7) are closed, and circulation thus established between tank (1) and condenser (5). Steam is then turned through pipe (4) into coil (9) and jacket (10), and the solvent still associated with the charge in chamber (2) and with the separated bitumen in tank (1) is distilled off. Finally steam is turned into perforated coil (8), and this removes the last traces of solvent from the residual bitumen.

Sellers, H. L., and Conyngton, H. R. and T., New Orleans, La. U.S. Patent 549399, (1895).

This process is based on the action of heated water in leaching bitumen from bituminous sand. Figure 36 illustrates a vertical section of the

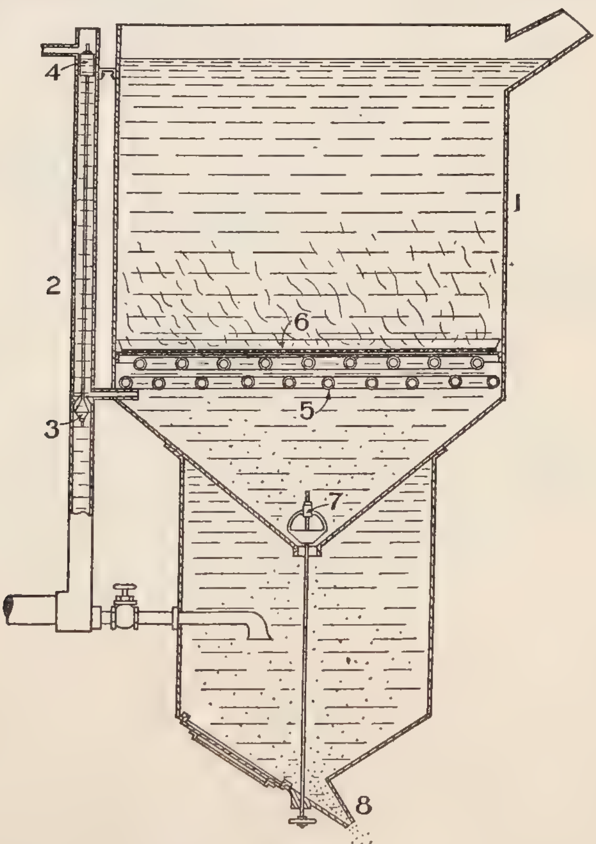

Fig. 36.—Apparatus for separation treatment of bituminous sand, H. L. Sellers and H. R. and T. Conyngton.

suggested apparatus. In this illustration (1) is a water tank, fed by pipe (2), and in which water level is controlled by valve (3) and float (4). Steam coils (5) are provided immediately below a metal diaphragm (6).

In operation crushed bituminous sand is charged into tank (1) and part separation of bitumen effected. Waste sand passes through diaphragm (6) and is discharged through offtakes (7) and (8). Bitumen is withdrawn through a spout in upper part of tank (1), and is further purified by heat treatment.

Simpson, Louis, 172 O'Connor St., Ottawa, Ont. Canadian Patents 234961, 235114. Additional patents pending.

Separation of bitumen from bituminous sand or other similar material, is effected by maceration in heated water. The following description, illustrated by Figure 37, refers to the process as outlined in Canadian patent 235114.

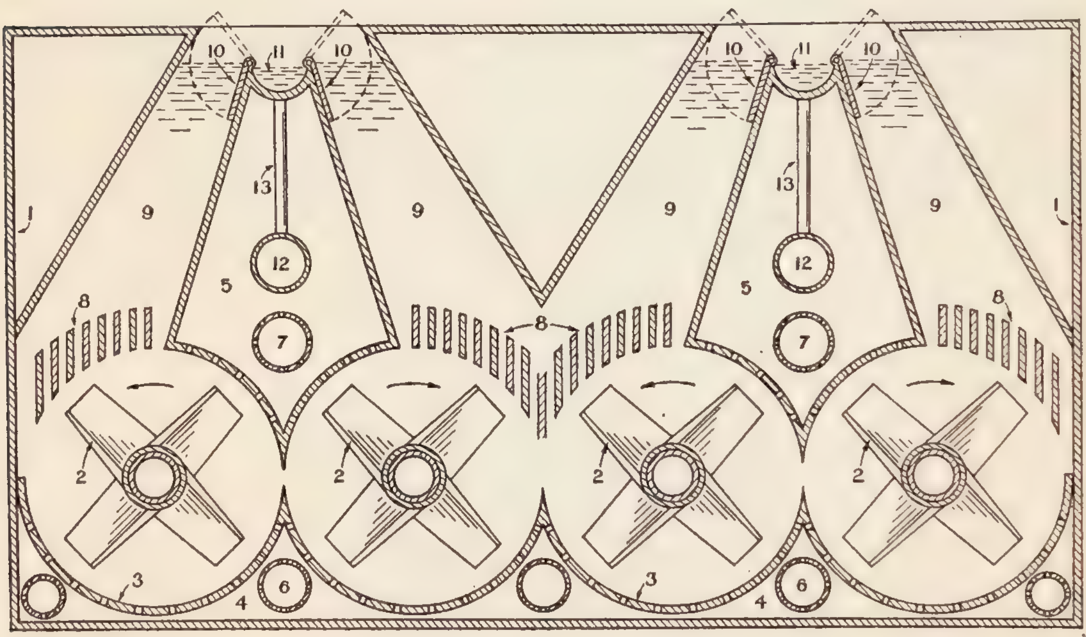

Fig. 37.—Apparatus for separation treatment of bituminous sand, Louis Simpson.

The apparatus is enclosed by an outer casing (1), within which are arranged a number of mixing conveyers (2), each pair rotating in opposite directions as indicated by arrows. Material to be treated is introduced through suitable conduits. The lower half of each conveyer is enclosed by a partly cylindrical trough (3), in which apertures are provided for admission of steam or water from compartments (4) and (5) and which is introduced through conduits (6) and (7). Separated bitumen rises through openings (8) to tapered channels (9), and is swept by movable arms (10) into trough (11), connecting with conduit (12) through pipe (13).

Information available indicates that demonstration of the above process has not been attempted.

Southern Asphalt Company, Woodford, Okla.

This company operated a small hot water separation plant near Woodford, Okla., about 1906. At the time of the writer's visit in 1913, the plant had been completely dismantled and details regarding methods adopted could not be secured.

Snyder Asphalt Company, Ardmore, Okla. (1908-10).

This company erected a small separation plant near Ardmore, Okla., about 1908. Material treated was a rather hard bituminous sandstone carrying from 10 to 12 per cent bitumen. The rock was disintegrated and part separation effected in a series of tanks filled with heated water.

In Figure 38, the four tanks are diagrammatically shown in longitudinal section. Bituminous sand, broken to pass a 6-inch ring, was introduced into tank No. 1, through hopper (1), which is provided with a control gate. In this tank, steam coils (2), extended the entire length, and the U-shaped bottom was steam-jacketed. A heavy longitudinal shaft (3), fitted with heavy curved blades, 4 inches wide and set at intervals of 8 inches, propelled the charged material. The bottom of the tank was provided with heavy replaceable wearing-plates. A sprocket-driven skimmer

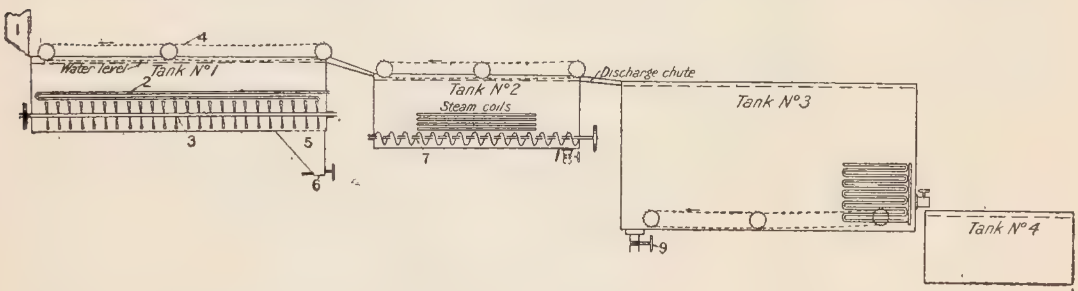

Fig. 38.—Apparatus for separation treatment of bituminous sand, Snyder Asphalt Company.

(4), removed such separated material as rose to the surface of the water, while spent sand fell through a coarse screen into hopper (5), and was discharged at a 6-inch core valve (6). The product from tank No. 1, flowed by gravity to a somewhat similar, though smaller tank No. 2. In this tank further settling of sand was effected, a 12-inch worm conveyer (7) replacing the heavy bladed agitator. Tank No. 3 was a settling-tank, in which water was drawn off at an upper level. The bitumen was discharged at 6-inch valve into tank No. 4, and the sludge and sediment were propelled by a scraper and discharged at sand valve (9). In tank No. 4, heat was again applied by means of steam coils arranged on sides and bottom, and final refining was effected. It is said that the product from this tank was 98 per cent pure.

Capacity of the above plant was approximately 3 tons refined product per 10 hours. It is claimed that better results were achieved than at any other plant of a similar type in Oklahoma. Operations were abandoned prior to 1911.

Streppel, August, Berlin, Germany. Canadian Patent 237286, (1924).

The process is based on the action of heated water and abrasion, for the removal of bitumen from bituminous sand. Figure 39 illustrates diagrammatically a vertical section of the suggested apparatus.

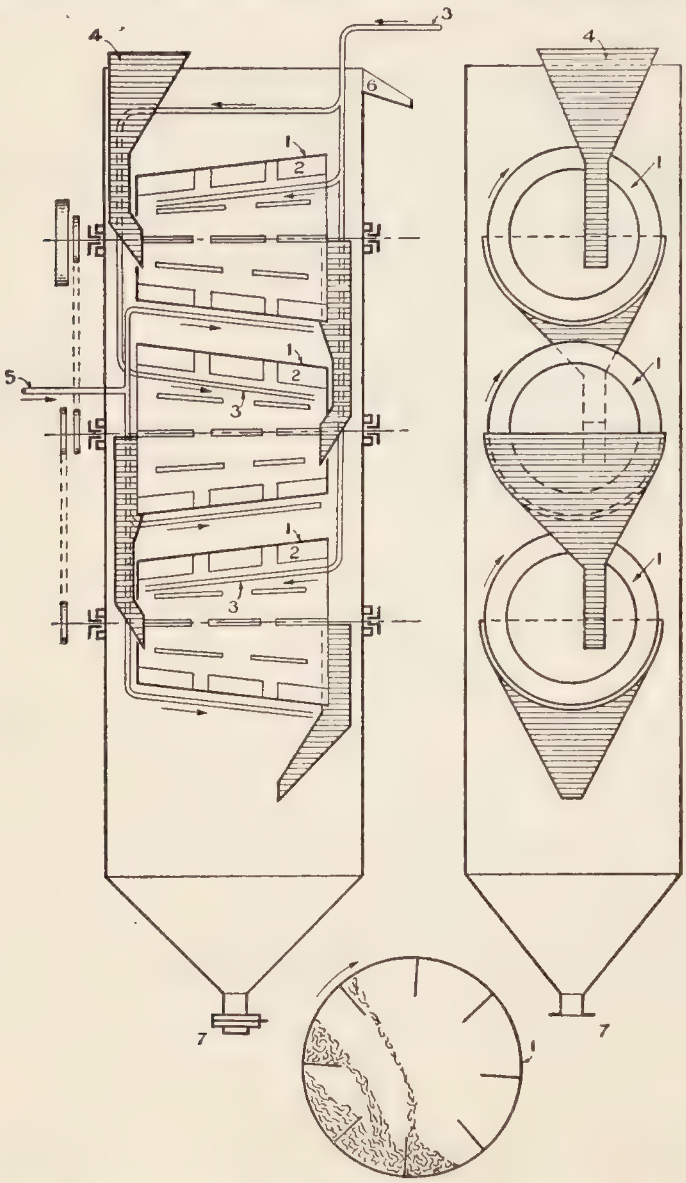

Fig. 39.—Apparatus for separation treatment of bituminous sand, August Streppel.

The principal features of the apparatus comprise a series of 3 or more horizontally arranged rolling-drums (1), which may be in the form of hollow truncated cones or inclined cylinders. The interior faces are fitted with lifting-plates or baffles (2). Water is introduced through pipes (3) and crude bituminous sand through hopper (4). Steam introduced through pipe (5) heats the water and the drums. A suitable overflow is provided at (6), and a discharge for waste sand at (7).

Tar Springs Refining Company, Tar Springs, Okla.[1]

In 1902-3, a plant was erected and operated near Tar Springs, Okla., for recovery of bitumen from soft bituminous sand using heated water as the separation medium.

The deposit consists of layers of uncompacted sand, impregnated with heavy hydrocarbons, and overlain by sand and clay. It appears that a series of individual impregnated beds, varying in thickness from 3 to 30 feet, and separated by partings of shale and clay, 5 to 40 feet in thickness, attains a total thickness of several hundred feet. Results of prospecting indicate that beds are irregular in thickness and extent, and in degree of impregnation.

The hydrocarbon content consists of from 10 to 14 per cent of semi-solid bitumen, and from 20 to 30 per cent of heavy petroleum. The presence of the latter greatly facilitates separation.

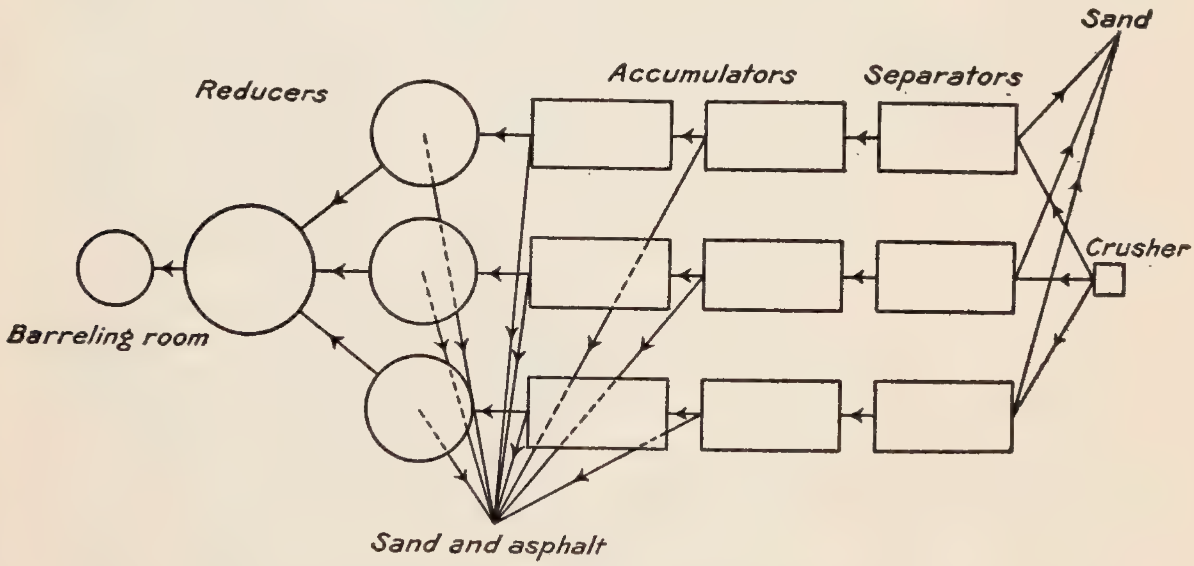

Fig. 40.—Flow-sheet illustrating separation process for treatment of bituminous sand, Tar Springs Refining Company.

All excavation by the Tar Springs Refining Company was by open-cut methods. As a result of leaching and oxidation, the upper portion of the bituminous strata was hard, and was therefore drilled and broken down by explosives. Holes were then bored by means of hand augers into the softer bituminous sand, which was loosened by the use of slow explosives, ploughed, and removed by wheel scrapers having a capacity of approximately 1 ton.

At the separation plant (Figure 40), the bituminous sand passed through a disintegrator or crusher, and was elevated to the charging-floor at the top of the building. Separation was effected in a progressive series of tanks, known as 'separators', 'accumulators', and 'reducers'.

[1] Crane, W. R.: Mines and Minerals, Mar. 1903, "Refining Methods used at Tar Springs, Okla.;" Engineering and Mining Journal; Dec. 17, 1903. "Asphalt Mining and Refining in the Indian Territory."

Separators were hot water tanks equipped with banks of steam coils, revolving screens, disintegrators, and devices for continuously discharging waste sand and removing separated hydrocarbons from the surface of the water. The temperature employed was approximately 180° F.

From the separators, the impure bitumen passed to the accumulators which were also heated by steam coils. In these all the water and the lighter hydrocarbons were driven off, and the bitumen and heavier petroleum passed to the reducers. In these direct heat was applied, final settling effected, and the refined product conducted to the barrelling room. Gate valves were used throughout.

Character and penetration of product was varied in accordance with market requirements but the bitumen was chiefly used in the preparation of the following commodities: roofing and insulating materials, paints, pipe covering or dips, and asphalt cement for paving purposes. The capacity of the Tar Springs plant was approximately 10 tons of finished product per 24 hours, and the initial cost of construction was $45,000. Reported cost of removing overburden and mining the bituminous sand was about 7 cents per cubic yard, and cost of refining, $10 per ton. It appears, however, that actual production cost of refined product was upwards of $15 per ton. Principal items, per ton of product, were as follows: fuel (wood at $1.25 per cord), $2.50; territorial charges, $0.60; labour, $2.21; transportation (by wagon), $2; barrels (4), $1.60. Average wages per day were: engineer-in-charge, $5.60; stationary engineer, $2.50; fireman, $1.25; foreman, $2.50; assistant foreman, $1.50; labourers (7), $1.25.

No attempt was made to recover oil vapours produced during heat treatment. It appears that the reducers, or "cooking" tanks, being of small capacity, were constantly overloaded, and were always a menace to life and property on account of sudden ebullition. Eventually one of the reducers caught fire from the furnace below. Sand, used to smother the fire, formed a crust which resulted in an accumulation of oil gas. An explosion, followed by fire, destroyed the plant.

Tait, Jas. D., 1125-11th Ave. W., Vancouver, B.C. Canadian Patent 237770. (Figure 41).

The process consists of separating the bitumen from bituminous sand, following disintegration in heated water. Bitumen, together with some sand, is floated to the surface of the water by means of a controlled current,the sand settles out and the bitumen is carried away by the current.

Principal features of the separation apparatus are a vertical cylindrical container (1), surrounded by an annular water jacket (2), provided with a steam heating-coil (3). Axially supported within the container (1), is an uptake pipe (4), the upper end of which is connected with a delivery flume (5). A rotating shaft (6), equipped with spiral conveyer, projects axially for a short distance into the lower end of uptake pipe (4). A hot water pipe (7), perforated toward its lower end, and equipped with stirring-arms, extends downward into uptake pipe (4), and may be rotated as desired.

Hot water is withdrawn as desired, from annular jacket (2), by pipe (8), connected with pump (9), and delivered into pipe (7). Flume (5) connects with settling-tanks (10) and (11) which, in turn, discharge into oil storage (12).

In operation, bituminous sand is delivered to container (1) through chute (12), and steam introduced into the coil (3). The heated water is delivered through pipe (7), and, assisted by the action of the stirring-arms,

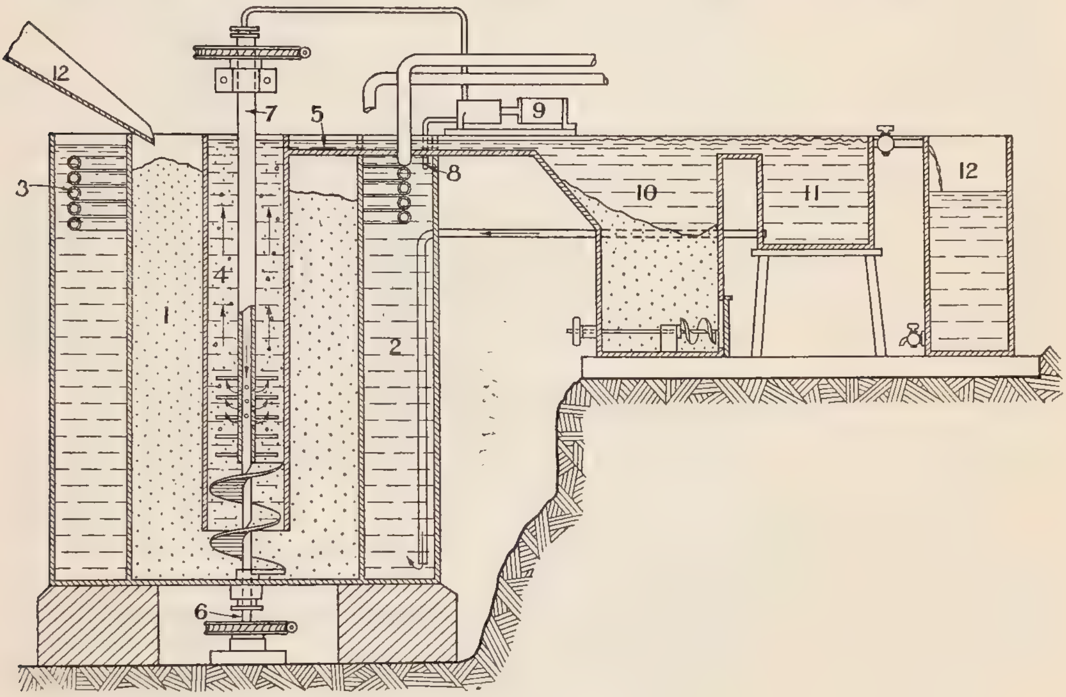

Fig. 41.—Process for separation treatment of bituminous sand, Jas. D. Tait.

causes disintegration of the bituminous sand fed from below. Assisted by the rising current of water, disintegrated particles rise to the surface and are carried to tank (10), where sand settles out. A mixture of bitumen and water pass to tank (11) where separation of water takes place. The bitumen itself then passes to storage tank (12).

So far as the writer is aware this process has not been demonstrated on a scale sufficiently large to indicate its commercial possibilities.

Thompson-Beeler Process, 1613 Race St., Denver, Colorado, (1924).

No definite information regarding this process is available.

Trumble, M. J. (Trumble Coal and Oil Shale Company), 1011 South Fremont Ave., Alhambra, Cal. Canadian Patents 235611, 236455, 237127, 237128, 237773.

The process comprises two essential features, namely, a series of disintegration tanks in which bituminous sand is acted on by a solvent (a petroleum distillate), and a tube furnace, in which the solvent together with bitumen leached from the bituminous sand is distilled.

Sand tailings from the disintegration tanks pass toward point of discharge through jacketed conveyers, and over banks of pipes carrying heated oil vapours. In this manner the solvent associated with sand tailings is distilled and recovered. The heated sand tailings then pass through a jacketed conveyer, where their heat is transmitted to the solvent-bitumen mixture flowing toward the tube furnace. Fractions are removed as soon as they are formed.

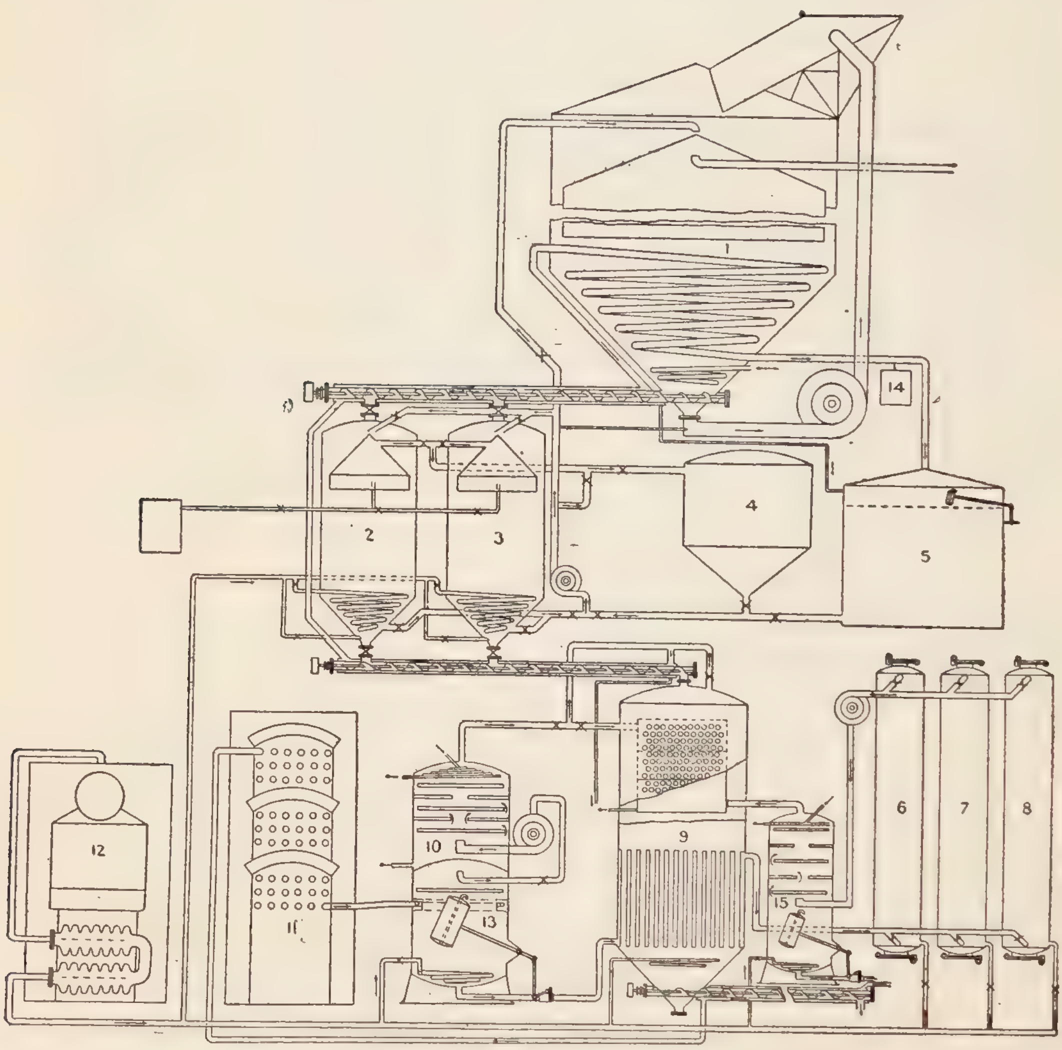

Fig. 42.—Diagrammatic flow-sheet of separation process for treatment of bituminous sand, M. J. Trumble.

In the diagrammatic flow-sheet (Figure 42)—

Crude oil sand is fed into the primary and separation tank (1) which is fitted with a coil condenser conveying solvent (distillate) to (5). Solvent plus recovered bitumen overflows from tank (1) and is led to crude oil storage.

(2 and 3), secondary separation tanks operated on same general principle as (1). In these, final leaching of bituminous sand is effected.

(4) is a solvent (distillate) tank for distillate which carries a percentage of leached out bitumen.

(5) is a solvent (distillate) tank for clean solvent used in separation of bitumen from crude oil sand. Into this tank also flow certain fractions recovered from the bitumen which is derived from the bituminous sand. An overflow control is provided so that surplus distillate is automatically removed.

(6, 7, 8) are distillation (cracking) chambers in which may be provided a bed of char (coke, spent shale or other material). On this char, fixed carbon is deposited, thus enriching it and rendering the product fit for use as solid fuel if desired. Superheated steam prevents excessive cracking and will carry over oil vapours by lowering temperature.

(9) is chamber in which solvent is recovered from sand tailings; (10) is dephlegmator; (11) is tube furnace in which solvent plus the bitumen which it has taken up is raised to 700° to 800° F. The counter-current circulation here is at high velocity (100 pounds pressure) and delivers vapours at pressure of 80 pounds to turbo-generator; (12) is a steam superheater; (13) is expansion chamber; and (14) is steam-still for separating out surplus gasoline, benzine, etc.

The crude oil sand is fed into tank (1) and is there acted on by solvent (distillate). The sand-bitumen-solvent mixture is circulated by means of centrifugal pump. In this tank a percentage of bitumen is recovered and this, together with the associated solvent overflows to storage.

The partly leached sand passes by jacketed conveyer to tanks (2) and (3) where the last traces of bitumen are recovered. From here solvent plus bitumen passes to storage. The sand tailings from (2) and (3) pass by jacketed conveyer to drier (9). The sand first comes into contact with a bank of coils carrying oil products at a temperature of possibly 400° F. and thence falls through a second bank of coils carrying oil products at a temperature of 700° F. From here the dried clean sand, from which the associated solvent has been recovered, passes to waste pile.

Solvent plus bitumen is led from crude oil storage through the spent sand conveyer from bottom of tank (9) absorbing some of the heat from the spent sand. On reaching furnace (11) it is heated to a temperature of 700° to 800° F. and thence passes to expanding-chamber (13). There the volatile is separated from the asphalt, and together with superheated steam, pass through turbo-generator to dephlegmator top (10) where, at a temperature of approximately 400° F., lubricating stock is recovered, and the lighter fractions pass through jacket of sand conveyer from (2) and (3) (preheating to some extent the leached sand) and thence through jacket about conveyer from leaching tank (1); thence through coil condenser in tank (1) to solvent storage (5).

Heavy asphaltum from (13) passes through lower part of (9); and thence to (6, 7 and 8), where cracking takes place. From here vapours (including steam, lubricating oil, and light distillates) are driven off, the fixed carbon remaining in the char, and enriching it as fuel. These vapours pass to dephlegmator (15) from which heavy lubricating stock is drawn off at the bottom, and light distillates pass to drier coils in (9) and thence through heat exchange system.

Certain details for recovery of fractions, at points where they may be formed, are omitted, but these fractions (notably gasoline, engine distillate and kerosene) are recovered as soon as they are formed, and are not allowed to enter the cracking still. Steam separators are assumed at points where they are required.

Complete heat recovery is a feature of the process. Gasoline and lubricating oils are the principal products, but other fractions can be made continuously as well as asphalt of any penetration as required.

Turner, C. Irlam, Manchester, England. Canadian Patent 194436, (1919).

This process was primarily designed for distillation of oil-shales. The inventor considers, however, that it is also well adapted to the distillation of bituminous sands.

The plant consists of a superheater capable of delivering an adequate amount of superheated low-pressure steam to the bottom of a vertical metal retort. The retort is provided with mechanical means for charging and discharging, and is continuous in action. An automatically controlled gas offtake valve is provided. The offtake valve being shut, the steam is forced upward and through the descending charge, which is heated gradually by it, under continuously increasing pressure to a temperature which varies throughout the retort, being lowest at the top and highest at the bottom. Increase in pressure raises the temperature, and at the same time tends to retard emission of vapours. When pressure has reached the desired maximum, the offtake valve automatically opens, pressure throughout the retort is at once reduced and is followed by an immediate drop in temperature, owing to escape of the steam and vapours to the condenser. Reduction of pressure permits of the formation and release of volatiles from all material possessing the temperature necessary to bring about destructive distillation.

Uvalde Rock Asphalt Company, Cline, Texas. U.S. Patent 581546.

In 1893, the Litho-Carbon Company undertook to develop a process for the treatment of bituminous limestone, carrying 12 to 15 per cent bitumen, the plant and property being later acquired by the Uvalde Rock Asphalt Company. The original extraction plant was re-designed and enlarged by the late H. A. Frasch at a cost of $60,000. As it represents an outstanding example of extraction by the use of petroleum naphtha, it is here described in some detail[1].

The plant comprised a series of steam-jacketed extractors constructed of boiler plate. Six or eight of these were connected in such a manner, that the solvent naphtha could flow from any extractor to and through the next in the series. Vapours from the various extractors were conducted to a central condenser, situated at an elevation which permitted the return of condensed solvent by gravity. There was thus established a constant circulation of solvent through the series of extractors, to the central condenser, and thence back again to the extractors.

[1] See also Mineral Industry, 1899.

The installation, as constructed, consisted of 6 extractors, which are shown in Figure 43. The extractors were 6 feet in diameter, and approximately 14 feet in height. They were provided with flanged openings (*b*) and (*c*) for charging and discharging the rock treated, with flanges for inlet and overflow pipes (*n*) and (*p*) with vapour pipes (*l*) (*i*), and with solvent return pipe (*g*). The outlet (*h*) served to draw off the solvent after extraction was complete, and was connected with the solvent storage tank.

In operation, each of the extractors was filled with crushed rock, delivered by elevator or tram at flanged openings (*b*). Naphtha was then admitted into the first of the series of extractors (No 1) through pipe (*g*), valves on pipe line (*g*) leading to other extractors being closed. Valve (*n*)

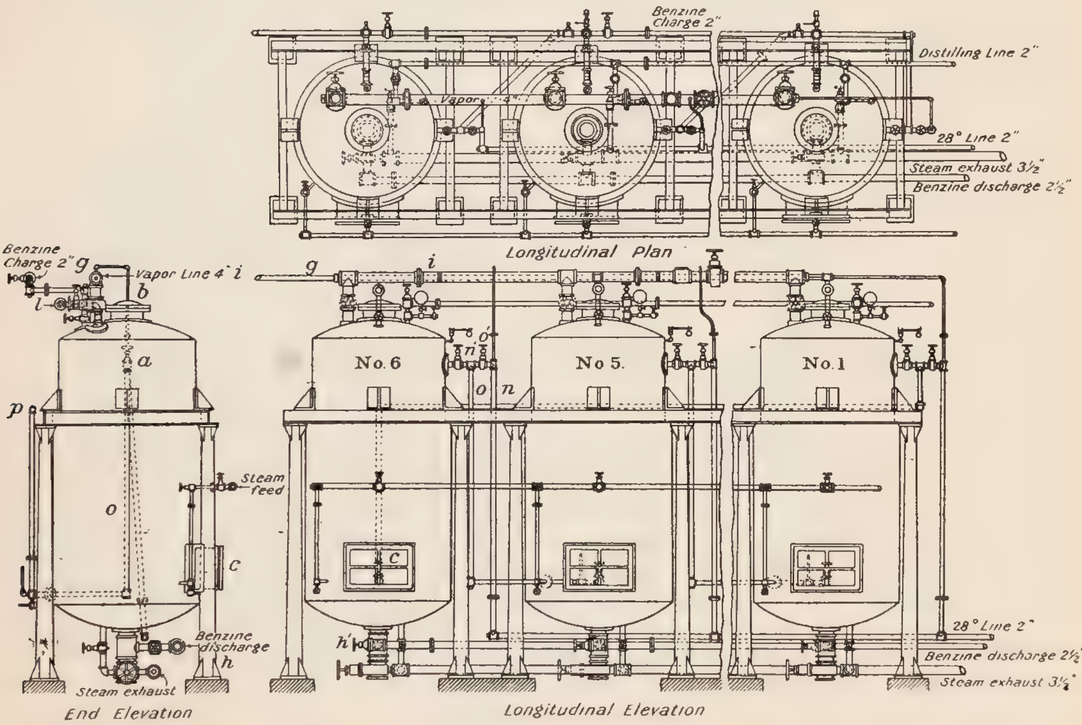

Fig. 43.—Apparatus for separation treatment of bituminous sand, Uvalde Rock Asphalt Company.

of extractor No. 1 was closed, while similar valves on the other extractors were opened. The solvent then flowed from extractor No. 1, through pipe (*o*) and valve (*n*) into extractor No. 2, thence passing in a similar manner to the other extractors of the series, and returning through pipe (*p*) to overflow pipe (*o*) of extractor No. 1. The valve (*o*) of that pipe being open, the solvent charged with bitumen, descended through pipe (*n*) into the main pipe line (*o*) which conducted it to storage or to suitable distilling apparatus. While the valve (*o*) of extractor No. 1 was open, similar valves on the other extractors were closed.

The contents of the extractors were brought to the desired temperature by introducing steam into the steam jackets. Vapours rising from the several extractors passed through the pipes (*i*) to the condenser, whence

they returned through pipe (*g*) to No. 1 extractor. Thus a continuous circulation of solvent, and a continuous flow of bituminous solution from No. 1 to No. 6 extractor, was maintained. In this manner, all the bitumen was eventually carried to the last vessel of the battery, and any desired degree of concentration could be secured. The bitumen was free from impurities, apart from a small percentage of solvent, which was subsequently removed in specially constructed stills. These stills consisted of a series of shallow pans, each provided with a heating coil and vapour outlet. Pans were arranged, one above the other, so that the hot liquid bitumen, ran in a tortuous stream from each pan to the one immediately below. About twenty of these pans formed a still, each being connected with a main vapour pipe and condenser. The pans were of ½-inch cast iron, 5 by 10 feet in dimension, and flanged on both sides. The bottom extended to within 10 inches of the end, and was finished off with a bridge, 2 inches high, which served as an overflow lip and maintained a depth of 2 inches of bitumen in the pan.

Sixteen extractors arranged in 2 batteries, together with 8 pan stills, had a capacity of over 100 tons of rock per 24 hours. Labour required to operate the apparatus proper, consisted of 2 men in charge of extractors, 4 men to empty and fill extractors (assuming rock to be delivered by automatic carrier) and 2 men in charge of pan stills. Each extractor, when filled, contained 700 gallons of solvent, the loss being less than 2 per cent.

The total expense of treating 100 tons of 15 per cent rock per day would be: mining, crushing, and delivery $25; labour (at $1.60 per 12-hour day) for extraction and distilling plants, $12; labour in packing and shipping $5; packages, $25; fuel and lighting, $25; engineman and assistant, $4; sundry labour, $5; loss of naphtha (at 8c. per gal.) $20; superintendence and office expenses, $15; total $136.

If carbon bisulphide were used instead of naphtha the circulation would be reversed. When naphtha is used, the flow in the extractors would be from the top downward, since naphtha becomes heavier as it becomes charged with bitumen. Carbon bisulphide becomes lighter in proportion to the amount of bitumen dissolved in it.

Whitaker-Pritchard Process; Pritchard Process Co., Ltd., 43 Victoria St., Toronto. Canadian Patents 165468, 244540, (1924).

A small research model, having a charged capacity of approximately 15 pounds bituminous sand, was demonstrated at Ottawa and at Toronto in 1924. Subsequently, a unit having a charged capacity of approximately 2,500 pounds was constructed in Toronto.

Essential features of the equipment consist of a vertical, metal retorting-chamber, a blower and a condenser. Figure 44 illustrates construction of the plant erected in Toronto. In this figure (1) is the retort shell constructed of iron 1½ inches in thickness, and separated by a 1¾-inch annular air space, from a perforated metal container (2). Direct heat is applied from two combustion chambers, one of which is indicated. Products of distillation are withdrawn through offtake (3), through

trap (4), to a 3-coil water-cooled copper condenser (5). Condensate is withdrawn from receiver (6) by means of hand-pump (7). Uncondensed gases pass through pipe (8), to a Roots blower (9), and thence to the top of the retort. From there, four extra heavy 1-inch pipes, encased for protection in 2-inch pipes (10), return the gases to the lower part of the retort, from which they rise through the mass undergoing distillation.

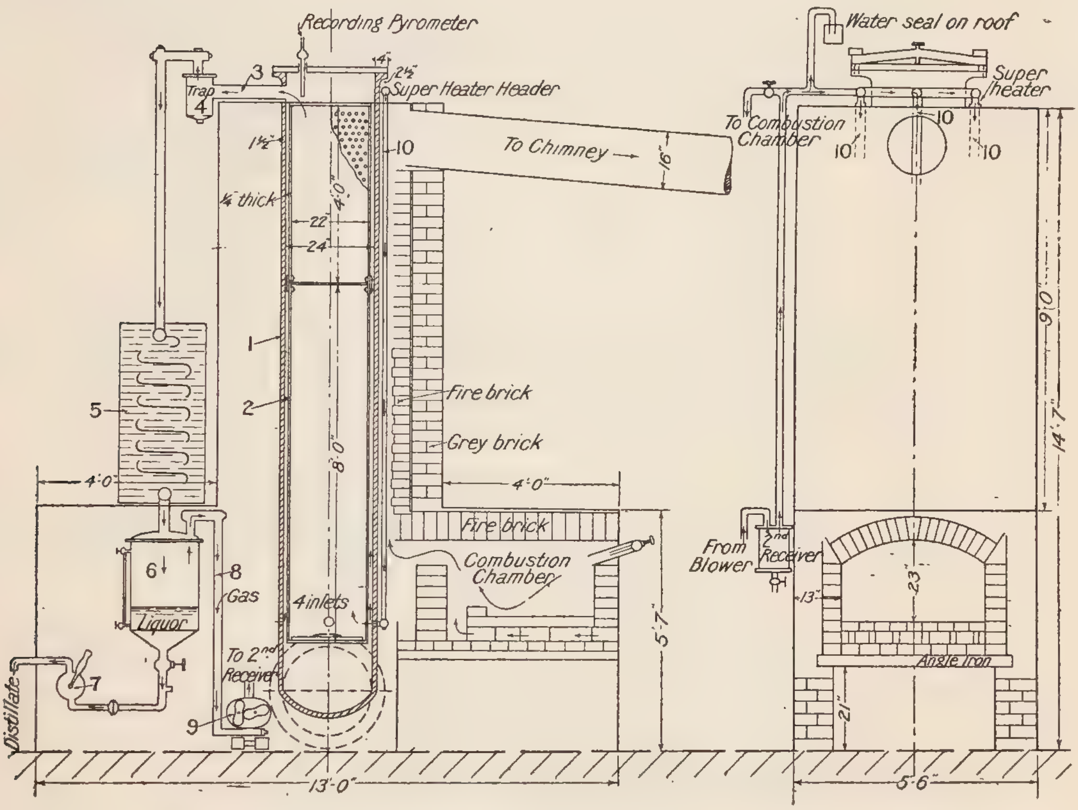

Fig. 44.—Experimental retort for distillation of bituminous sand, Whitaker-Pritchard process.

During October and November, 1924, a number of experimental runs were made with the above retort, the maximum temperature attained being 745° F. During early stages of distillation, petroleum free from water was recovered, but as distillation progressed, an emulsion of petroleum and water was condensed. A sample of the petroleum was forwarded by the Pritchard Process Company to the laboratory of the Imperial Oil Company at Sarnia for examination with the following results.

1. *Fresh bituminous sand—*	
Oil content by weight	9·04 per cent
Bitumen content	12·07 "
2. *Recovered oil—*	
Baumé gravity	20·7
Specific gravity	0·930
Flash	No
Cold test	O.K. at 0° F.
Colour	green
S.D	1·58
B.S	0·1 per cent.
Odour	sour
I.B.P	198° F.
Per cent off at 221° F	1·0
" " 284° F	5·0
" 350° F	9·0
" " 374° F	12·0
" " 400° F	13·0
" " 437° F	16·0
" " 460° F	19·0
" " 500° F	24·0
" " 560° F	34·0
" " 600° F	43·0
3. *The tar—*	
Specific gravity	1·098
Bitumen content by weight	97·89 per cent
There was not enough material to make a distillation or flash test and the viscosity of the tar was too high to determine.	
4. *The dry carbonized sand—*	
Bitumen content by weight	3·12

Willis, G. M., Chicago, Ill. U.S. Patent 918628, (1909).

This process is based on the action of heated water and agitation in leaching bitumen from bituminous sand.

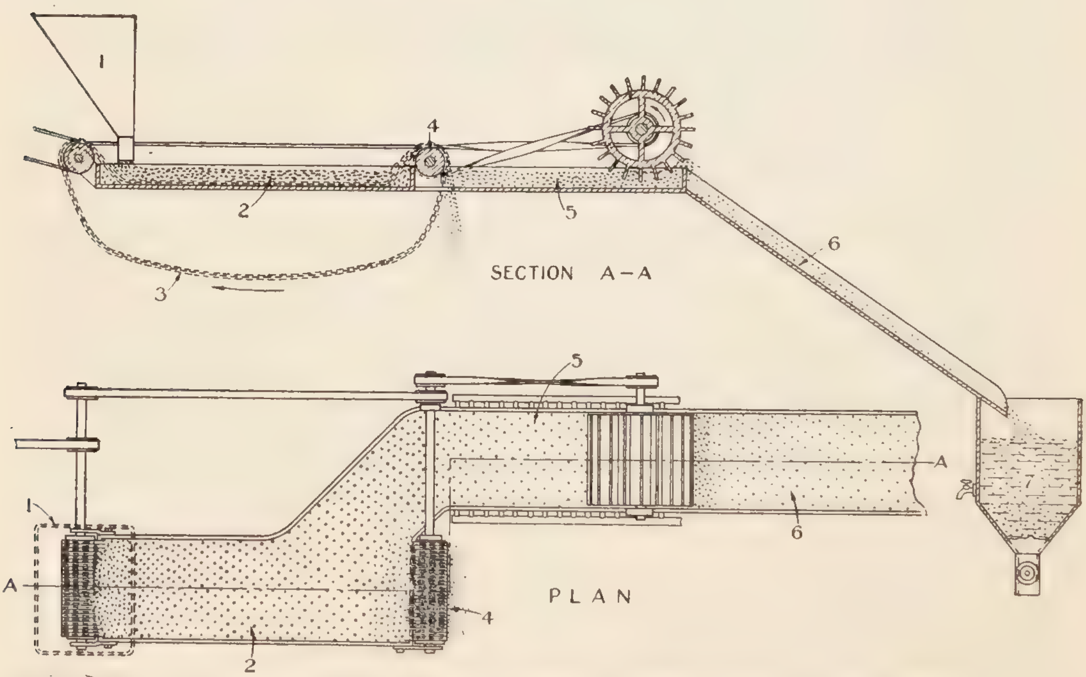

Fig. 45.—Apparatus for separation treatment of bituminous sand, G. M. Willis.

Figure 45 illustrates the suggested apparatus in plan, and section along a line A-A.

Crushed bituminous sand is introduced through hopper (1), into separation tank (2) which is filled with water to a suitable depth and heated from below. As the bituminous sand is propelled along the tank by carrier belt (3), a part of the sand settles out, and is discharged at (4). A mixture, consisting of 40 per cent bitumen together with sand and water, passes into heated water tank (5), where further separation takes place. The product from this tank, consisting of a mixture of 70 per cent bitumen together with sand and water, flows down the inclined plane (6), on which it is heated to approximately 600° F. In this manner all the moisture is driven off, and a mixture of bitumen and sand is discharged into a steam heated settling-tank (7). In this tank, the sand settles out and the bitumen is drawn off. The sand-bitumen sludge is then returned for re-treatment.

Wilson, Thomas Holy, Edmonton, Alberta. Canadian Patent 214551, (1921).

This process has been devised for distillation of hydrocarbons associated with bituminous sand. Figure 46 illustrates diagrammatically ver-

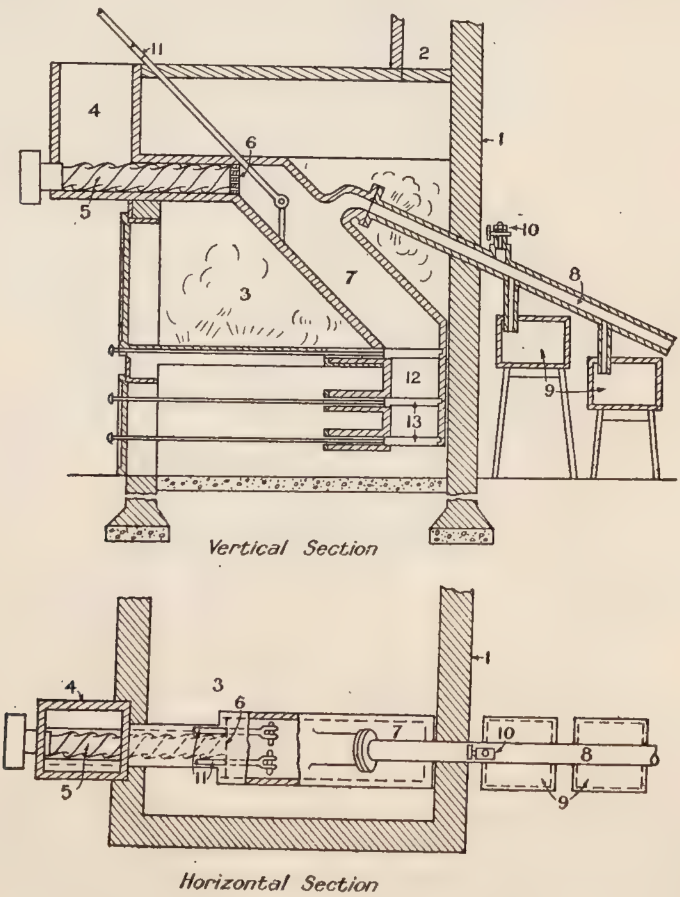

Fig. 46.—Apparatus for distillation treatment of bituminous sand, T. H. Wilson.

tical and horizontal sections of the suggested apparatus. On this figure (1) represents a furnace, with a flue (2), and a firebox (3); (4) is a hopper

in conjunction with which is a screw-conveyer (5). This feeds bituminous sand through a perforated plate (6), into a distillation retort (7), provided with offtake (8) leading to oil storage (9), and equipped with safety valve (10). Pivoted pusher bars (11), are provided for clearing the retort. Below retort (7) are a number of compartments (12), equipped with slides (13), designed to receive sand residue.

Wurtz, H., Newark, N.J. U.S. Patent 821323, (1906).

The apparatus referred to in this patent consists essentially of heating-furnace, distillation chamber and condenser. The distillation chamber or retort is provided with a series of trays on which the bituminous sand or other material is placed; while being charged, the trays are removed from their position within the furnace. The action is thus intermittent. Figure 47 illustrates a vertical section of the assembled apparatus.

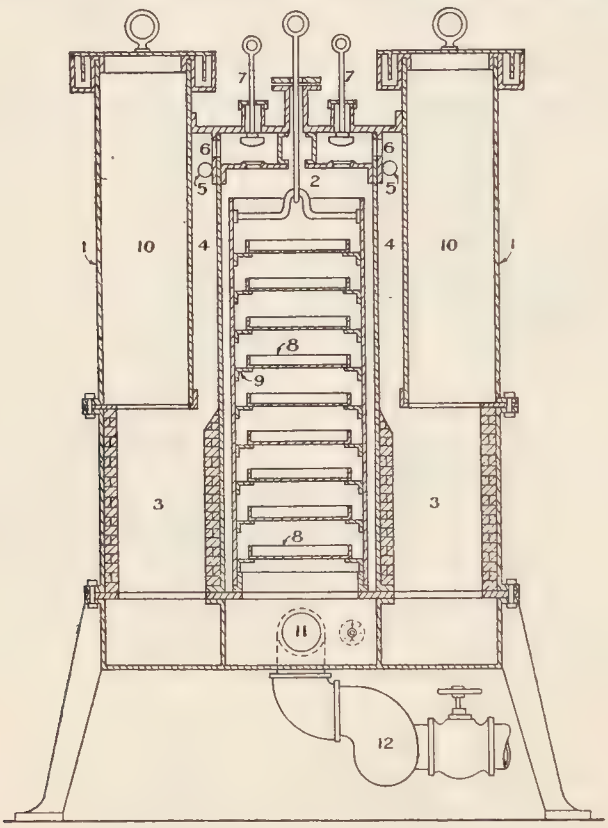

Fig. 47.—Apparatus for distillation treatment of bituminous sand, H. Wurtz.

The exterior structure (1) is sheet iron, and consists of an inner retorting-chamber (2), fireboxes (3), and flues (4), the latter being connected with a stack by means of draft openings (5). Openings (6), connect furnace flues with the retorting chamber, admission of combustion gases being controlled by check valves (7). The retorting-chamber is provided with a series of metal trays (8), secured to a suitable casing or frame (9), the ends of the trays being staggered in order to permit of

free circulation of gases. Below the retorting-chamber, and connected therewith, is a longitudinal vapour exit (11), connected with a rotary exhaust fan (12).

In operation, the tray casing and trays are removed from the retorting-chamber by means of an overhead trolley, and the trays charged with material to be distilled. On starting the furnaces, draft openings (5) are opened for a short time in order to accelerate combustion. The exhaust blower is then started, and the draft openings closed. Combustion gases from the flues, are drawn downward over the contents of the trays and, together with distillation products, are withdrawn to a suitable condenser.

Information indicates that demonstration of the above process has not been undertaken.

CONCLUSIONS

So far as the writer is aware, no successful process for the recovery of hydrocarbons from Alberta bituminous sand has as yet (April, 1925) been commercially demonstrated. On the other hand, certain processes now being seriously studied appear to possess real merit.

In connexion with any attempts that may be made to secure capital for development purposes, it therefore appears desirable to carefully consider, not only the recovery process itself, but also the personnel of the company interested.

Efficient commercial recovery of hydrocarbons associated with Alberta bituminous sand, presents a problem that is apparently not more difficult than many metallurgical problems that have already been solved. The problem will only be solved by intelligent research, mechanically sound design, and careful, correlated experimentation.

From a consideration of the foregoing pages, which indicate the general trend of invention in this field, it will be seen that processes for recovery of hydrocarbons from bituminous sand may be grouped into three general classes.

(1) Separation of associated bitumen through the leaching action of heated water, with or without the addition of reagents. Mechanically, preliminary separation by such methods is entirely feasible. Apparently the principal difficulty consists in removing associated water, and the finer sand particles and silt, during final purification.

(2) Separation of associated bitumen through the leaching action of certain solvents such as petroleum distillates. Such separation is more rapidly effected and gives a cleaner product. Subsequent recovery of the low-boiling solvents used presents fewer difficulties than the removal of water.

(3) Recovery of associated hydrocarbons by heat distillation. Such recovery implies higher temperatures, and results in the production of varying percentages of unsaturated compounds. Subsequent recovery of heat from a large mass of inert waste sand, apparently constitutes one of the chief problems.

As a mechanical problem, recovery of hydrocarbons from bituminous sand is entirely feasible by each of the above general methods. As a commercial problem such recovery is largely a question of supply and demand. As in the case of oil-shales, commercial development will be possible when, for any reason, the cost of well petroleum and its derivatives reaches a point approximating the cost of production of hydrocarbons from bituminous sand. Such development implies adequate financial resources, and should not be undertaken by men of small capital or by those who desire quick returns on their investment. Meanwhile it appears that much duplication of effort exists, and that greater co-operation is desirable between Government and private investigators, and between the private investigators themselves.

APPENDIX I

ON THE USE OF THE TERMS "TAR SAND" AND "ASPHALT," AS APPLIED TO THE BITUMINOUS SAND DEPOSIT OF NORTHERN ALBERTA[1]

The following comment regarding the use of the expression 'tar sand' is by Mr. Herbert Abraham:—

"From an accurate scientific standpoint it is not proper to apply the term 'tar sand' to the material occurring in Alberta. Strictly speaking, the term 'tar' should be applied to *distillates* resulting from the pyrogenous decomposition, *i.e.*, destructive distillation of organic substances such as bones, wood, peat, lignite, coal, pyrobituminous shales, etc. The sand in question is a natural product consisting of sand matrix having its voids filled with semi-liquid asphalt.

"About the middle of the last century, native deposits of liquid or semi-liquid asphalts were referred to as 'mineral tar.' Since these deposits from a physical standpoint consisted of a soft and sticky black substance which was analogous in appearance to the 'tar' derived from the destructive distillation of bones (*i.e.* bone-tar), coal (*i.e.* coal-tar), that may have been proper from a layman's point of view, but as science gradually unravelled the chemical composition of these respective substances, the term 'asphalt' has been extended to cover the natural deposits of this character, whereas the word 'tar' has gradualy been restricted to the pyrogenous distillates obtained by industrial operations.

"Hence, in accordance with the above interpretation, the sand deposits of Alberta should strictly be termed 'asphaltic sand' and not 'tar sand.'"

Many pages from the works of many writers have been devoted to attempts to define "bitumen" and "asphalt." In order, therefore, to avoid confusion it is desirable to indicate the meaning which at present attaches to these two terms in Europe and in America.[2]

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[1] "Terms used in connexion with asphalt for highway work." Brochure No. 5. The Asphalt Assn., New York City.

[2] Abraham, H.; Proc. Eighth International Congress of Applied Chemistry.
Richardson, C. The Modern Asphalt Pavement 1908.
British Engineering Standards; Nomenclature of Tars.
American Society of Testing Materials; Standards, 1918.
Spielmann, P. E.. Bituminous Substances. 1925.
Pitches, Bitumens and Asphalts. Report 76, 1916.
Chemistry 1912; Jour. Ind. & Engr. Chem., Jan. 1913.
Abraham, H., Asphalts and Allied Substances, 1918.
Day, Dr. David T., in Engr. & Min. Journal, July 27, 1912, Eng. & Min. Jour., Dec. 30, 1911.
Richardson, Clifford, in Journal Am. Chem. Soc., Sept. 1910, pp. 1032-1040.
Chemical Constitution and Differentiation between Natural and Artificial Asphalts, Marcussen, F., in Mitt. Kgl. Materials-prüfungsampt, 30.2 Farben Ztg. 225-8.
The Asphaltic Rocks of the United States and their uses in street paving, Peckham, S. F., Trans. Am. Inst. Chem. Engr., 5245.
Other definitions by Tillson, G. W.; Dow, A. W.; and others will be found in "Street Paving and Paving Materials," Chap. III, by Tillson, G. W.

In Europe, the term asphalte may be defined as a rock consisting of carbonate of lime naturally impregnated with pure bitumen, to form an homogeneous whole. The percentages of each constituent vary widely, 7 to 13 per cent of bitumen, and 73 to 91 per cent of carbonate of lime, being ordinary limits. In certain instances, a wider range is met with. At 50° to 60° C, most natural rock asphalts (though not all bituminous limestones) fall to pieces. When again heated between 110° and 120° C, and compressed, they again assume their original compact and homogeneous form. The mean specific gravity of recognized European asphalts is 2·220.

In America, the application of the term asphalt has been the subject of much discussion, and minority reports have been prepared by members of committees appointed by the American Society of Testing Materials. The following definition appears in the Year Book (1915) of the Society:—

"Asphalts—Solid or semi-solid native bitumens, solid or semi-solid bitumens obtained by refining petroleums, or solid or semi-solid bitumens which are combinations of the bitumens mentioned, with petroleums or derivatives thereof, which melt upon the application of heat, and which consist of a mixture of hydrocarbons and their derivatives of complex structure largely cyclic and bridge compounds".

The following definition, which appears to overcome most objections, is by Herbert Abraham:—

"Asphalt.—A term applied to a species of bitumen, also to certain pyrogenous substances of dark colour, variable hardness, comparatively non-volatile; composed of hydrocarbons substantially free from oxygenated bodies; containing relatively little or no crystallizable paraffines; sometimes associated with mineral matter, the non-mineral constituents being fusible, and largely soluble in carbon bisulphide and whose distillate, fractioned between 300° and 350° C., yields considerable sulphonation residue."

In the bulletin entitled "Asphalt, Related Bitumens, and Bituminous Rock," issued by the Mineral Resources Division of the United States Geological Survey, in 1915, the following introductory note, by John D. Northup, occurs:—

"In a broad sense the term natural asphalt may be used to denote all types of naturally occurring asphaltic substances that are employed in the arts and industries. It is so used in this chapter in reference to the asphaltic materials commercially mined or quarried in the United States. They comprise the native bitumens, maltha, graphamite, and gilsonite; the so-called "pyrobitumen" elaterite, the bitumen impregnated rocks, sandstone, limestone and shale; and the cerous hydrocarbon, ozokerite. The term "manufactured asphalt", as used in this chapter includes both oil asphalt, a solid or semi-solid by-product obtained in the distillation of asphaltic or semi-asphaltic petroleum, and residual asphaltic oils or pitches, the viscous residues of the evaporation or distillation of petroleum of asphalt base to a point where all the burning oils and often some of the heavier distillates have been removed."

According to the above definition, bituminous sand would thus be classed as a sub-variety of rock asphalt.

The writer considers, however, that the terms asphaltic or bituminous sand may be more correctly applied to the softer uncompacted grades of materials, and asphaltic or bituminous sandstone to the harder and more compact grades.

On both continents, the term "bitumen" has practically the same significance. "Bitumen" may be defined[1] as "mixtures of native or pyrogenous hydrocarbons, and their non-metallic derivatives which may be gases, liquids, viscous liquids, or solids and which are soluble in carbon bisulphide."

Commenting on the above definition, Mr. Herbert Abraham suggests that the use of the term "bitumen" be restricted to native products only. He also points out that, where bitumens are associated with mineral matter, (as in the case of rock asphalt), only a portion of the bitumen may be soluble in carbon bisulphide, the mineral matter, of course, being insoluble. Again certain native bitumens are only partly soluble in carbon bisulphide, even though they may be substantially free from mineral constituents, (as in the case of a deposit referred to in Coos county, Oregon, and described on page 85 of "Asphalt and Allied Substances").

[1] Am. Soc. Test. Mat. Year Book, 1915.

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